Automobile Engineering

A General Reference Work

FOR REPAIR MEN, CHAUFFEURS, AND OWNERS; COVERING THE CONSTRUCTION, CARE, AND REPAIR OF PLEASURE CARS, COMMERCIAL CARS, AND MOTORCYCLES, WITH ESPECIAL ATTENTION TO IGNITION, STARTING, AND LIGHTING SYSTEMS, GARAGE DESIGN AND EQUIPMENT, WELDING, AND OTHER REPAIR METHODS

Prepared by a Staff of

AUTOMOBILE EXPERTS, CONSULTING ENGINEERS, AND DESIGNERS OF THE HIGHEST PROFESSIONAL STANDING

Illustrated with over Fifteen Hundred Engravings

FIVE VOLUMES

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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost Automobile Firms and Manufacturers in making these volumes thoroughly representative of the very latest and best practice in the design, construction, and operation of Automobiles, Commercial Vehicles, Motorcycles, Motor Boats, etc.; also for the valuable drawings, data, illustrations, suggestions, criticisms, and other courtesies.

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IGNITION GENERATOR AS DESIGNED FOR REO CARS
Courtesy of Remy Electric Company, Anderson, Indiana

REMY STARTING MOTOR AS DESIGNED FOR REO CARS
Courtesy of Remy Electric Company, Anderson, Indiana

GRAY AND DAVIS STARTING AND LIGHTING INSTALLATION ON FORD CARS

Foreword

THE period of evolution of the automobile does not span many years but the evolution has been none the less spectacular and complete. From a creature of sudden caprices and uncertain behavior, it has become today a well-behaved thoroughbred of known habits and perfect reliability. The driver no longer needs to carry war clothes in momentary expectation of a call to the front. He sits in his seat, starts his motor by pressing a button with his hand or foot, and probably for weeks on end will not need to do anything more serious than feed his animal gasoline or oil, screw up a few grease cups, and pump up a tire or two.

¶ And yet, the traveling along this road of reliability and mechanical perfection has not been easy, and the grades have not been negotiated or the heights reached without many trials and failures. The application of the internal-combustion motor, the electric motor, the storage battery, and the steam engine to the development of the modern types of mechanically propelled road carriages, has been a far-reaching engineering problem of great difficulty. Nevertheless, through the aid of the best scientific and mechanical minds in this and other countries, every detail has received the amount of attention necessary to make it as perfect as possible. Road troubles, except in connection with tires, have become almost negligible and even the inexperienced novice, who knows barely enough to keep to the road and shift gears properly, can venture on long touring trips without fear of getting stranded. Astonishing refinements in the ignition, starting, and lighting systems

have lately been effected, thus increasing the reliability of the electrical equipment of the automobile as well as adding greatly to the pleasure in running the car. This, coupled with the extension of the electrical control to the shifting of gears and other important functions, has made the electric current assume a position in connection with the gasoline automobile second only to the engine itself. Altogether, the automobile as a whole has become standardized, and unless some unforeseen developments are brought about, future changes in either the gasoline or the electric automobile will be merely along the line of greater refinement of the mechanical and electrical devices used.

¶ Notwithstanding the high degree of reliability already spoken of, the cars, as they get older, will need the attention of the repair man. This is particularly true of the cars two and three seasons old. A special effort, therefore, has been made to furnish information which will be of value to the men whose duty it is to revive the faltering action of the motor and to take care of the other internal troubles in the machine.

¶ Special effort has been made to emphasize the treatment of the Electrical Equipment of Gasoline Cars, not only because it is in this direction that most of the improvements have lately taken place, but also because this department of automobile construction is least familiar to the repair men and others interested in the details of the automobile. A multitude of diagrams have been supplied showing the constructive features and wiring circuits of the principal systems. In addition to this instructive section, particular attention is called to the articles on Welding, Shop Information, and Garage Design and Equipment.

¶ For purposes of ready reference and timely information so frequently needed in automobile operation and repair, it is believed that these volumes will be found to meet every requirement.

Table of Contents

VOLUME IV

* For page numbers, see foot of pages.

† For professional standing of authors, see list of Authors and Collaborators at front of volume.

TYPICAL AUTO-LITE GENERATOR
Courtesy of Electric Auto-Lite Company, Toledo, Ohio

TYPICAL AUTO-LITE STARTING MOTOR WITH BENDIX DRIVE
Courtesy of Electric Auto-Lite Company, Toledo, Ohio

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART VI

ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

PRACTICAL ANALYSIS OF TYPES—(Continued)

LEECE-NEVILLE SYSTEM

Six-Volt; Two-Unit; Two-Wire

Generator. Standard shunt-wound bipolar type, combined with ignition timer and distributor driven by a worm gear on the armature shaft. The generator is mounted on the left side of the engine and is driven by the pump shaft (Haynes 1913 installation, and subsequent models to date).

It differs from the standard shunt-wound machine in that the shunt field is connected to the regulating third brush. This brush collects current from the commutator and excites the field, so that a strong shunt field is provided at comparatively low speeds. As the speed increases, the voltage supplied to the shunt field decreases, even though the total voltage between the main brushes may have increased. This weakens the field and prevents the output of the generator from increasing with the increased speed. At higher speeds it acts somewhat similarly to a bucking-coil winding in that it further weakens the field and causes the generator output to decrease still more. The closer the third brush is set to the main brush just above, the greater will be the output of the machine; moving it away from the main brush decreases the output.

Regulation. Generators of the 1915 and 1916 models are controlled by armature reaction through a third brush, the field coils receiving their exciting current from the armature through this brush. The position of the latter on the commutator is shown at *B*, Fig. 293. A slight rotation of this brush relative to the com-

mutator changes the electrical output of the machine. As adjusted at the factory this brush is set to give a maximum output of 15 amperes at 7½ volts. (All generators for 6-volt systems are wound to produce an e.m.f. of 7½ volts, or thereabout, in order that the voltage of the generator may exceed that of the battery when the latter is fully charged. The e.m.f. of generators for 12-volt and 24-volt systems also exceeds that of their batteries in about the same proportion. Otherwise, the generator would not be able to force current through the battery.)

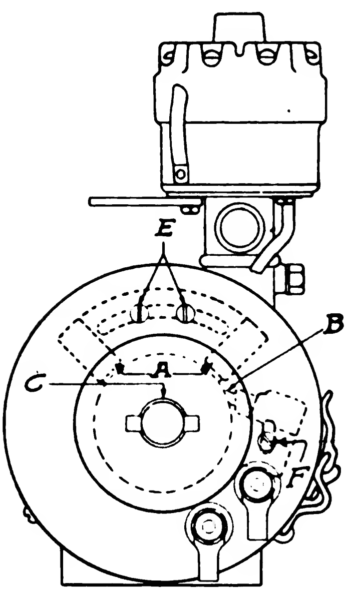

Fig. 293. Diagram of Arrangement of Brushes on Leece-Neville 6-Volt Generator

Starting Motor. The motor is of the bipolar series-wound type driving the engine through a roller chain and an over-running clutch.

Instruments. An indicating type of battery cut-out is employed, thus combining the functions of the cut-out and ammeter in one device. The details of this device are shown in Fig. 294. *O* is the winding or coil of the electromagnet of which the U-shaped bar 8 forms the magnetic circuit. At *4* is the pivoted armature, normally held in the *OFF* position as shown by a spring, when no current is passing, and adapted to be drawn against the pole pieces of the magnet when the latter is excited by the charging current. As the two-wire system is employed, the cut-out breaks both sides of the battery-charging circuit and it is provided with six current-carrying contacts on each of the sides of the circuit. Four of these, which carry most of the current, are *copper* to bronze,

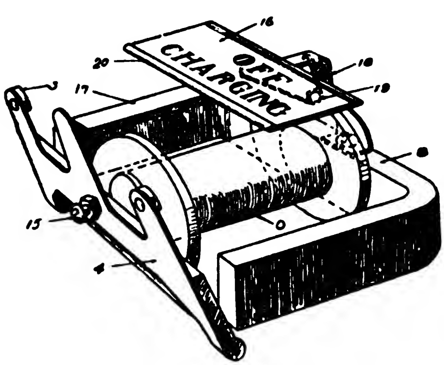

Fig. 294. Details of Leece-Neville Indicator

while those that take the spark in breaking the circuit are *cophite* to iron and are actuated by a spring. The indicating target *16* is held in the *OFF* position by the spring *19* when no current is passing, and this reading appears in the opening of the panel on the cover. When the generator starts and the cut-out closes, the target is moved to bring the word *CHARGING* in the opening. The same panel also carries the three-way lighting switch controlled by buttons. The central button closes the circuit to the headlights and tail lights in the usual manner, while the upper button throws the headlights in series-parallel connection. As this doubles the resistance, it halves the voltage passing through the lamps, and they, accordingly, burn dimly. The lower button controls the cowl light over the instruments on the dash.

Wiring Diagram. Fig. 295 illustrates the Haynes 1915 installation. While two wires are employed for connecting all the apparatus, it will be noted that the storage battery and the dry-cell battery are grounded by a common ground connection. This is to permit using current from the storage battery for ignition, the corresponding ground to complete the circuit being noted at the ignition coil, close to the distributor. The connections *G* and *B* on the panel board are those of the generator and the battery to the indicating battery cut-out, the connections of three lighting switches being shown just to the right. In Fig. 296 is shown the Leece-Neville installation in White cars.

Instructions. Never run the engine when the generator is disconnected from the battery unless the generator is short-circuited, as otherwise it will be burned out in a very short time. This applies to all lighting generators except those protected by a fuse in the field circuit, in which case the fuse will be blown. The Leece-Neville generator can be short-circuited by taking a small piece of bare copper wire and connecting the two brush holders together with it. Instructions for short-circuiting other makes are given in connection with the corresponding descriptions.

Later models of the Leece-Neville generator are provided with a circuit-breaker. On the Haynes 12-cylinder models, this is mounted on top of the generator, while in some cases it is combined with the ammeter on the dash. To protect the generator and battery, there is a 5-ampere cartridge fuse under the cover of this circuit-breaker.

Fig. 295. Wiring Diagram for Leece-Neville System on Haynes Light Six

When this fuse blows out, both the generator and the circuit-breaker become inoperative. Any one of the following conditions may cause

Fig. 296. Wiring Diagram of Leece-Neville System on White Cars

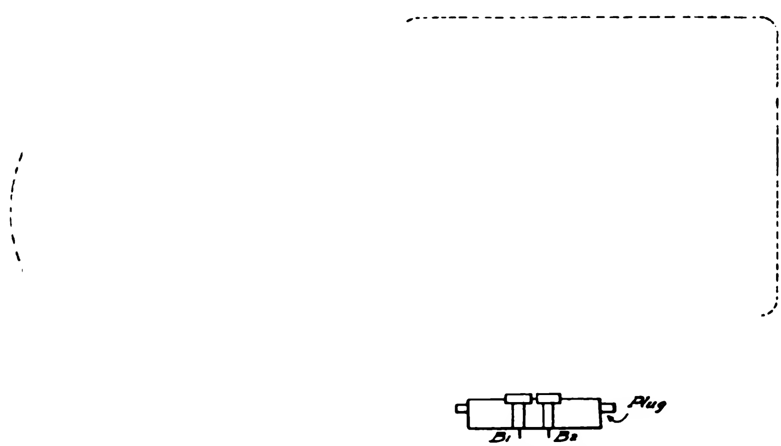

Fig. 297. Wiring Diagram of Generator and Circuit-Breaker Circuits for Leece-Neville System
Courtesy of The Seece-Neville Company, Cleveland, Ohio

this fuse to blow out: loose or corroded connections at the battery; an open circuit in the wiring on the battery side of the cut-out; not sufficient water in the battery; output of the generator too high;

allowing the main brush directly above the third brush to stick in its holder; a loose connection at the point A_2, Fig. 297; improper insulation between the wires B_1 and B_2 in the connector plug, Fig. 297. By an open circuit is meant an actual break at a connector or a terminal, or in the wiring itself, while a loose connection signifies an insecurely fastened terminal or wire, at a junction box, or at any other part of the system. If there is a short-circuit in the field winding of the generator, this also will cause the fuse to blow out.

Testing the Field Winding. While a short-circuit in the field winding of any generator is a rare fault, there are times when the trouble cannot be traced to any other part of the system. To test the Leece-Neville generator for this, connect the negative terminal of the portable testing ammeter to F_1, Fig. 297, while the positive terminal of the motor must be connected to the positive terminal of a 6-volt storage battery; the negative terminal of the battery is to be connected to the third brush when drawn from its holder. If the indication of the ammeter is above 4 amperes, there is a short-circuit in the field windings. In such a case, the generator should be returned to the manufacturers for repairs.

With the engine running, the working of the generator should be inspected from time to time. In case there is excessive sparking or "arcing" between the brushes and the commutator, examine the connections at F_1 and A_1 and see that the screws are perfectly tight, as these screws sometimes work loose and are responsible for this arcing which is destructive to the commutator. The loosening of the connections at F_1 and A_1 will have no effect on the fuse; but if the connection at A_2 loosens, the fuse will burn out. When inspecting the operation of the generator, see that the brushes are making good even contact with the commutator, and wipe away all particles of dust and grit from around the brushes and their holders. With the engine stopped, see that the brushes move freely in their holders. This should always be done where a car has been laid up for some time (before starting the engine) as the brushes, through disuse, will have a tendency to stick.

The fuse in the circuit-breaker has no effect whatever on the output of the generator, so that a larger fuse must not be inserted in case the generator is not delivering its rated output or more. The makers supply a 5-ampere fuse for this purpose, and if a fuse of

heavier capacity is employed, it will cause both the circuit-breaker and the generator so burn out. This will be the case also where a "jumper" is resorted to, i.e., a piece of wire or other metal bridging the fuse clips so that the fuse is cut out of the circuit. It must be borne in mind, however, that these fuses are more or less fragile and are likely to become damaged by careless handling. A fuse whose connections have been loosened up is likely to blow out on that account, so before inserting a fuse in the clips of the circuit, it should be examined to see that the ferrules on each end of the cartridge are perfectly tight. Where a good fuse has been inserted and it blows out, the cause should be ascertained before inserting another fuse.

Regulating Brush. In case the generator output falls off as shown by its inability to keep the battery properly charged, the battery itself and all connections being in good condition, and a proper amount of day running being done to provide the necessary charging current, the trouble may be in the regulating brush of the generator. Test by inserting an ammeter, such as the Weston portable or any other good instrument with a scale reading to 30 amperes, in the line between the generator and the battery. Run the engine at a speed corresponding to 20 miles per hour, at which rate the ammeter should record a current of approximately 15 amperes. If the ammeter needle butts against the controlling pin at the left end of the scale instead of showing a reading, it indicates that the polarity is wrong, and the connections should be reversed. Should there be no current whatever, the needle will stay perfectly stationary except as influenced by vibration. If the ammeter shows a reading of less than 15 amperes, the current output of the generator may be increased by loosening the set screw holding the third brush and rotating the brush slightly in the same direction as the rotation of the armature. This should be done with the generator running and the ammeter in circuit, noting the effect on the reading as the brush is moved. To decrease the output, it should be moved in the opposite direction until the proper reading is obtained, after which the brush must be sanded-in to a good fit on the commutator. It may sometimes occur that sufficient movement cannot be given the third brush without bringing it into contact with one of the main brushes. This must be avoided by loosening the two set screws *E*, Fig. 293, and moving the main brush holder away

from the third brush until there is no danger of their touching. After securing the desired adjustment, fasten the third brush in place again, stop the engine, and then reconnect the generator to the battery. Do not cut the ammeter out of the circuit while the generator is running.

To Adjust Third Brush. Before making any adjustment of the third brush when it is suspected that any trouble with the current supply is due to the generator, the output of the generator should be tested. On a car equipped with lamps totaling 250 candle power or more (this refers to White busses), the generator should produce 20 amperes. Run the engine at a speed sufficient to drive the car 15 o 16 miles per hour on direct drive and note the reading of the dash ammeter. In case the car has seen considerable service, it may be well to check the dash ammeter with the more accurate portable ammeter described in connection with other tests in previous and subsequent sections. Where the car lighting system totals 250 c.p. or over, and the ammeter reading shows more than four amperes above or below 20, the generator should be adjusted to give its rated capacity of 20 amperes—as every 15 c.p. less than 250 c.p. used on the car, lower the output of the generator by one ampere. By making the adjustments in this manner, the storage battery will be amply protected.

Before making any generator adjustments, test the storage battery with the hydrometer. Do not add any distilled water just previous to making this test unless the level of electrolyte is right down to the plates so that sufficient liquid cannot be drawn into the hydrometer; in this case, add water and charge the battery for at least one hour before making the hydrometer test. If the specific gravity of the electrolyte is 1,250 or over, and the generator is found to be delivering less than the rated lamp load, no adjustment of the generator should be made.

To increase the output of the generator, rotate the third brush in the direction of rotation of the armature; to decrease the output, move the brush against the direction of rotation. Adjustments should be made with the engine standing. Loosen the screw at the rear of the commutator housing shown at the point *F*, Fig. 293. This releases the third brush holder, and the brush may then be moved in the direction desired. It should be moved only a short distance,

and the generator then should be tested until the desired output is secured. In case the third brush should come in contact with the main brush above in the course of adjustment, it will be necessary to move the main brushes. To do this, loosen the two set screws *E*, Fig. 293, and move the main brush holder far enough away from the third brush so that there is no possibility of contact between them. When the desired location is found, sand-in the third brush to the commutator and also clean the commutator with a piece of worn sandpaper as described in the section on Sanding-In the Brushes (Delco instructions); if it has been necessary to move the main brushes, they should be sanded-in also. The brush holder screws should be well tightened after making any adjustments to prevent any possibility of the vibration and jolting loosening them up and throwing the generator out of adjustment again.

Brush Replacements. Never replace any of the brushes on either the generator or starting motor with any but those supplied by the manufacturer of the system for this purpose. Motors and generators adapted for use on electric-lighting circuits are usually fitted with plain carbon brushes. These are not suitable for use on automobile generators or starting motors owing to their resistance being much higher. Due to the low voltage of electric apparatus on the automobile, special brushes of carbon combined with soft copper are usually employed. Brushes also differ greatly in hardness, and a harder brush than that for which the commutator is designed will be liable to score it badly besides producing a great deal of carbon dust, which is dangerous to the windings. This, of course, applies to all makes of apparatus and not merely to that under consideration.

Generator or Motor Failure. For failure of the generator or of the starting motor, see instructions under Auto-Lite, Delco, and Gray & Davis, bearing in mind, however, that the system under consideration is of the two-wire type, so that in using the test lamp to locate short-circuits a connection to the frame or ground is not always necessary. The short-circuit may be between two adjacent wires of different circuits. Given properly installed wires and cables, there is less likelihood of short-circuits in the wiring of a two-wire system. Defective lamps will not infrequently prove to be the cause, as, in burning out, a lamp often becomes short-circuited.

NORTH EAST SYSTEM*

Twelve-Volt, Sixteen-Volt, or Twenty-Four-Volt; Single-Unit; Single-Wire or Two-Wire, According to the Installation

Dynamotor. The dynamotor is of the four-pole type, with both windings connected to the same commutator. It is designed for installation either with silent-chain drive—as on the Dodge, Fig. 298, in which case the drive is direct either as a generator or as a motor—or with a special reducing gear and clutch for driving from the pump or magneto shaft of the engine. In the latter type, the starting switch is mounted on the gear housing, which is integral with

Fig. 298. North East Dynamotor with Silent-Chain Drive. Starting Switch Shown at Right
Courtesy of North East Electric Company, Rochester, New York

the bedplate of the dynamotor. In this case the drive as a generator is $1\frac{1}{2}$ times engine speed, while as a starting motor the reduction through the gear is approximately 40 : 1.

Regulation. The regulation is by means of a differential winding or bucking coil, in connection with an external resistance automatically cut into the shunt-field circuit by a relay in series with the battery cut-out. See "limiting relay", Fig. 299. The "master relay" is the battery cut-out, and the condenser is to reduce sparking at the contacts of these relays.

Protective Devices. There is a fuse in the field circuit of the generator, but fuses are not employed on the lighting circuits.

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*The voltage of any system may be determined by counting the number of cells in the storage battery, and multiplying by 2 in the case of a lead battery, or multiplying by $1\frac{1}{4}$ where an Edison battery is used.

STARTING SWITCH.

RESISTANCE. LIMITING RELAY. MASTER RELAY. RESISTANCE

Fig. 299. Diagrammatic Section of North East Dynamotor, Showing Regulator (Limiting Relay) and Cut-Out (Master Relay)

Wiring Diagrams. A graphic diagram of the North East

Fig. 300. Diagrammatic Layout of North East Installation on Dodge Cars
Courtesy of North East Electric Company, Rochester, New York

installation on the Dodge is shown in Fig. 300. This is a 6-cell or 12-volt system single-wire type. The sprocket on the forward end

Fig. 301. Diagrammatic Layout of North East 12-Volt Installation on Krit 1915 Automobiles (14-Volt Lamps)

of the machine drives from a similar but much larger sprocket on the forward end of the crankshaft of the engine through a silent chain. The wiring diagram of the Krit 1915, Fig. 301, will be recognized as being the same as the Dodge, except for the use of two wires throughout. Fig. 302 shows the wiring diagram of an 8-cell or 16-volt system, but the battery is divided for the lighting circuits so that 8½—9-volt lamps are used, whereas 14-volt bulbs are necessary on the Dodge installation as the entire battery is used in series for lighting. The wiring of the 12-cell or 24-volt system is shown in Fig. 303. In this case the battery is divided for lighting so that 7-volt lamps are employed. Such a system is usually designated as 24—6-volt, while the previous one would be a 16—8-volt. The North East installation for Ford cars is 24—14-volt. With the exception of the Dodge, the two-wire system is employed on the installations mentioned.

Instructions. The indicator shows when the battery is charging or discharging and accordingly should indicate OFF when

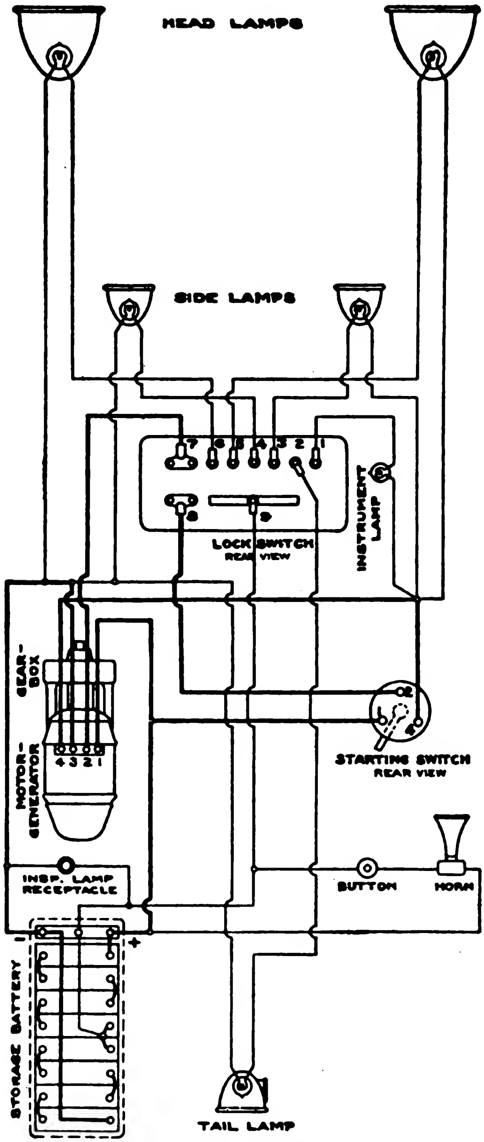


Fig. 302. Wiring Diagram for 16-Volt North East System Using 8½—9-Volt Lamps

TAIL LAMP

Fig. 303. Wiring Diagram for 24-Volt North East System Using 7-Volt Lamps

the engine is idle and no lamps are lighted. A discharge reading under such conditions would indicate the presence of a ground, short-circuit, or failure of the battery cut-out to release. Should the generator fail to charge the battery, note whether the field fuse has been blown by short-circuiting the fuse clips with the pliers or a piece of wire while the engine is running at a moderate speed. Look for cause of failure before replacing the fuse. If the fuse has not blown, see whether battery cut-out is operating; look for loose connections at generator, cut-out, and battery. If the battery is properly charged, loose connections are also most likely to be the cause of failure of the starting motor; or, any of the instructions covering brushes, commutator, etc., as given previously, may apply.

Battery Cut-Out and Regulator (*Relays*). In every case where it is necessary to make repairs on starter-generators equipped with the earlier type cut-out and regulator (relays), 1283 (12-volt), 1860 (16-volt), 2501 (24-volt), 1900 (16-volt), and 2503 (12 and 24-volt), it is advisable to replace the cut-out entirely, installing a later and improved type, 1196 (12-volt), or 1197 (24-volt and 16-volt). In order to adapt the starter-generator to the 1196 and 1197 cut-out, or relay units, it is necessary to cut out the bosses on the commutator end bearing in which the studs holding the original relay were screwed. This will provide the clearance required to prevent grounding of the nuts which secure the units to their baseboard. As a further precaution against grounding, it will be necessary to cut away that portion of the gasket retainer which would be liable to come into contact with the armature of the master relay.

Fasten down the baseboard which carries the relays by screwing the resistance unit studs into the holes which were used for the former resistance studs. Before making connections on the relay, draw tight all leads which come from inside the starter-generator so as to take up whatever slack they have; then tie them together with string to prevent their slipping back. No loose wire must be left inside the starter-generator, because of its tendency to be drawn in between the armature and the pole pieces. The connections on the four-terminal type starter-generator are made as follows:

Looking at the starter-generator from the driving sprocket end, the main terminals 1, 2, 4, and 3 of the starter-generator are considered as being numbered in anti-clockwise rotation, Fig. 304. Viewing

the relay unit as mounted on the starter-generator with the larger, or master relay, at the left, the four binding posts *a*, *b*, *c*, and *d* are designated from left to right in the same illustration. To relay binding post *a*, connect lead (red) coming from starter-generator terminal 2. To relay binding post *b*, connect lead (black) coming direct from starter-generator terminal 3. To relay binding post *c*, connect lead (green) from starter-generator terminal 4. To relay binding post *d*, connect lead (yellow) from starter-generator shunt-field coils. It is always advisable to check the identity of the leads by inspection and test.

In order to make a positive distinction between the *d* lead and the *b* lead, both of which are in electrical connection with the starter-generator terminal 3, the following test should be made: Using the test-lamp outfit, send current from starter-generator terminal 3, through each of these wires in turn, and note appearance of the lamp. When the direct lead (*b* lead) is in circuit, the lamp will burn with full brilliance, but when the *d* lead, which includes the starter-generator shunt-field coils, is in circuit, the lamp will be noticeably dimmer.

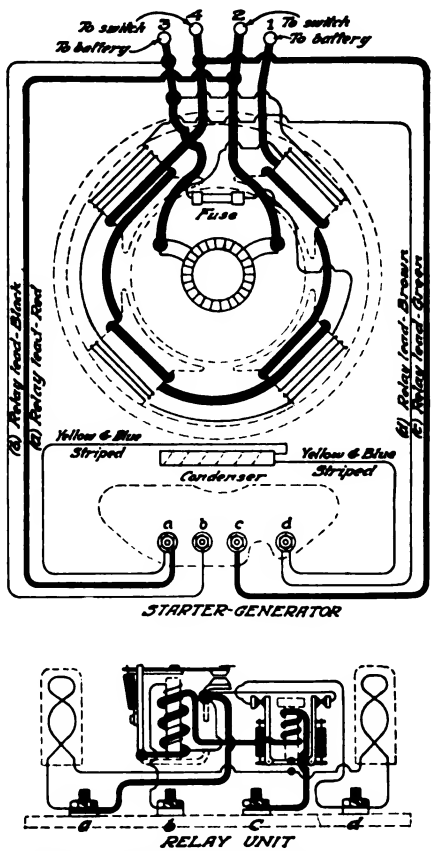


Fig. 304. Internal Wiring Diagram for North East Model "B" Starter-Generator

Five-Terminal Type Unit. The connections on the five-terminal type generator-starter unit are made as follows: Looking at the starter-generator, Fig. 305, from the driving sprocket end, the main terminals 1, 5, 2, 4, and 3, respectively, of the unit are numbered in anti-clockwise rotation (to the left). Viewing the relay unit as

mounted on the starter-generator with the master relay at the left, the four binding posts *a*, *b*, *c*, and *d* are designated from left to right as shown in the illustration. Proceed with the instructions as given for the four-terminal type starter-generator as given. The new type relays 1196 and 1197 are regularly furnished with local connections, as shown in Fig. 304, but it will be necessary to make the following alterations when applied to the five-terminal type starter-generator, so that the relay connections will conform to the diagram in Fig. 305. Remove the jumper lead that connects the frame of the master relay to the rear contact terminal on the limiting relay; remove from relay binding post *a* the left-hand resistance-unit lead. Lengthen this lead by splicing a piece of the same kind of wire to it, and solder it to the limiting relay contact terminal, from which the jumper has been removed. To this terminal must also be soldered the lead coming from starter-generator terminal 5. (In some starter-generators this lead includes the field fuse.)

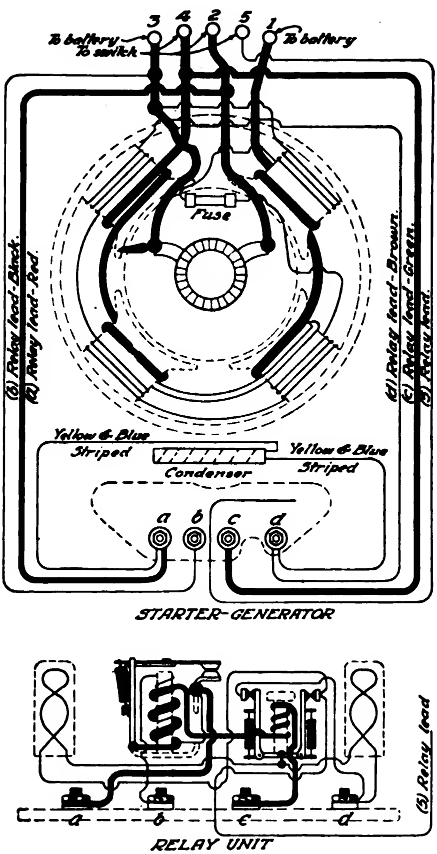


Fig. 305. Internal Wiring Diagram for Model "D" and Model "F" Starter-Generators

The condenser in the early models is mounted between the field coils. One condenser lead must either be connected to the relay binding post *a* as shown in either Fig. 304 or Fig. 305 or be spliced to the wire leading to it. The other condenser lead must either be connected to the relay binding post *d* or spliced to the shunt-field wire leading to it.

Fig. 306. View of Essential Parts of North East Starting Switch
Courtesy of North East Electric Company, Rochester, New York

Starting Switch. When its operation indicates that the contactor blades have worn, the starting switch should be dismounted, and, if necessary, new blades should be inserted. To disassemble the switch, proceed as follows: (1) Remove the spring 2265, Fig. 306, on the switch case 2365; (2) remove the cotter pin from the collar 2416; (3) withdraw the shaft and lever 2401, together with the spring 1818; (4) remove the three screws which hold the cover 2404 in place, and remove the cover; (5) remove the stop 2457; and (6) disconnect the spring 1813 from the arm of the ratchet and remove the contactor member 2344.

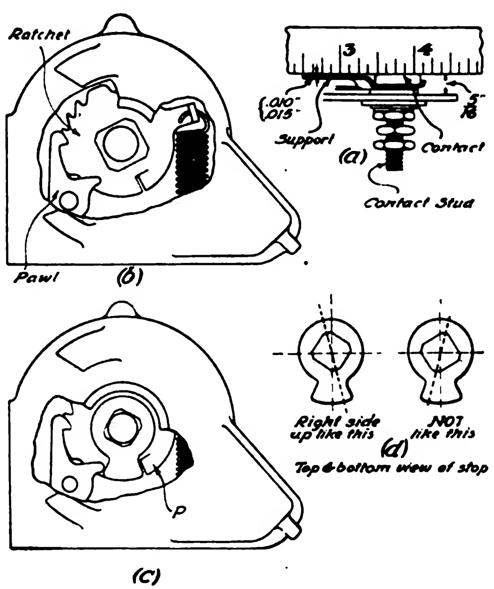


Fig. 307. Assembly of Starting Switch
Courtesy of North East Electric Company, Rochester, New York

If, upon inspection, the contacts are found to be in such a condition that their renewal is necessary, make a replacement of the entire cover member 2404 and the entire contactor 2344. Before placing these new parts in the switch, the following points should receive careful attention: the front edges of the contact blocks should be slightly rounded so as to eliminate the possibility of these edges catching on each other when the switch is being operated. The supports on the cover must be adjusted so that they lie parallel with the faces of the contact blocks.

The upper surfaces of the supports must be .010 to .015 inch lower than the contact surface of the block. Care should be taken that the upper surface of the contact blocks are $\frac{5}{16}$ inch above the inner surface of the cover. A small steel straightedge laid upon the face of the contact block and extended over the supports, as shown in Fig. 307 (*a*), will serve as a means of checking these dimensions.

Before placing in service, the contact surfaces must be carefully cleaned and lubricated with a very small quantity of vaseline. To reassemble the switch: (1) Connect the spring 1813, Fig. 306, to the arm of the ratchet; (2) place the contactor member 2344 in the switch case in such a position that the ratchet will lie against the pawl 1830; and (3) hold the switch case in the left hand, lever side up, and insert the right forefinger through the hole in the switch case and introduce the pawl into the first notch of the ratchet, Fig. 307 (*b*); (4) hold these parts carefully in position and replace the cover 2404, Fig. 306, fastening it to the switch case by means of the three screws; (5) insert the stop through the hole in the switch case and replace it upon the ratchet plate in such a position that the elongated portion of the stop will lie between the raised projection which is found on the ratchet plate and the end of the short lever on the pawl as shown in Fig. 307 (*c*). It is very important that the stop be placed in the switch right side up, Fig. 307 (*d*) illustrating the proper method of doing this. (6) Place the spring on the shaft and replace the shaft in the switch, taking care while entering the shaft not to disturb the arrangement of any of the switch parts; (7) replace the collar and the cotter pin; and (8) connect the spring 2265 with the lug on the switch case. A drop of light oil should be applied to the bearing point at each end of the switch shaft 2401.

Switch Tests. To determine whether the switch has been assembled correctly, pull the lever through the full length of its stroke and allow it to return slowly to its initial position. If the switch is properly assembled, three distinct clicks will be heard while the lever is being moved through its stroke, and a snap will occur just before the lever comes back to its initial position. The switch should be tested electrically, as follows:

Ground Test. Using the lamp-test set as shown in Fig. 263 and following Part V, hold one contact point on the switch case and then connect the other to the two contact studs. The test lamp will not light unless there is a ground.

Operation Test. Hold one of the test points in contact with each of the two studs, and turn the lever through its stroke. If the switch is in proper working condition, the test lamp will light up just after the first click of the switch and continue to burn until the final snap occurs.

TABLE V

Gray & Davis Test Outfit

Mechanical Characteristics									
Shown on Plate	Model	Drg. No.	Volts	Rota-tion	Arm. Dia. (in.)	Style Coupling	Style Termi-nals	Charge Rate Amp.	Torque Ft.-Lb @ Amp.
118, 127	A	1000	16	C.C.	$3\frac{1}{4}$	Shaft	4 Post	7	12 4
118, 127	A	2000	16	C.	$3\frac{1}{4}$	Shaft	4 Post	7	12 4
	A-4	1070	16	C.	$3\frac{1}{4}$	Oldham	5 Lead	7	12 4
	A-4	1080	16	C.C.	$3\frac{1}{4}$	Oldham	5 Lead	7	12 4
123	B-1	1102	16	C.	$3\frac{3}{4}$	Oldham	5 Post	6	22 9
123	B-1	1103	16	C.C.	$3\frac{3}{4}$	Oldham	5 Post	6	22 9
123	B-2	1106	24	C.	$3\frac{3}{4}$	Oldham	5 Post	6	36 15
123	B-2	1109	24	C.C.	$3\frac{3}{4}$	Oldham	5 Post	6	36 15
126	F-1	1210	24	C.	$3\frac{3}{4}$	Sprocket	4 Post	4	36 15
125	D-1	1220	24	C.	$3\frac{3}{4}$	Oldham	4 Post	4	36 15
125	D-1	1221	24	C.C.	$3\frac{3}{4}$	Oldham	4 Post	4	36 15
124	D-6	1223	24	C.	$3\frac{3}{4}$	Flange	4 Post	5	36 15
124	D-6	1224	24	C.C.	$3\frac{3}{4}$	Flange	4 Post	5	36 15
123	B-3	1246	12	C.	4	Oldham	5 Post	7	35 21
123	B-3	1247	12	C.C.	4	Oldham	5 Post	7	35 21
123		1248	12	C.	$3\frac{3}{4}$	Oldham	5 Post	7	32 20
123		1249	12	C.C.	$3\frac{3}{4}$	Oldham	5 Post	7	32 20
125	D-2	1250	12	C.	4	Oldham	4 Post	7	35 21
125	D-2	1251	12	C.C.	4	Oldham	4 Post	7	35 21
126, 126-A	F-2	1252	12	C.	4	Sprocket	4 Post	7	35 21
							4 Lead		
126	F-2	1253	12	C.C.	4	Sprocket	4 Post	7	35 21
126-A							4 Lead		
124	D-7	1254	12	C.	4	Flange	4 Post	7	35 21
124	D-7	1255	12	C.C.	4	Flange	4 Post	7	35 21
125	D-2	1256	12	C.	$3\frac{3}{4}$	Oldham	4 Post	7	32 20

TABLE V—(Continued)

Gray & Davis Test Outfit

Mechanical Characteristics								Approximate Electrical Characteristics							
										Master Relay			Lim. Rl	Resis. Unit	
Shown on Plate	Model	Drg. No.	Volts	Rotation	Arm. Dia. (in.)	Style Coupling	Style Terminals	Charge Rate Amp.	Torque Ft.-Lb. @ Amp.	Cuts in Pos. Amp.	Cuts Out Neg. A.	Air Gap (in.)	Air Gap (in.)	No. of Spools	Total Resis.
125	D-2	1257	12	C.C.	$3\frac{3}{4}$	Oldham......	4 Post...	7	32 200	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19ω
126		1258	12	C.	$3\frac{3}{4}$	Sprocket.....	4 Post...	7	32 200	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19ω
126-A							4 Lead...								
126		1259	12	C.C.	$3\frac{3}{4}$	Sprocket.....	4 Post...	7	32 200	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19ω
126-A							4 Lead...								
80-A	D-9	1264	12	C.	4	Sprocket.....	4 Lead...	6.5	35 210	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19ω
80-A	D-9	3520	12	C.C.	4	Sprocket.....	4 Lead...	7	35 210	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19ω
126	F-3	3500	24	C.	4	Sprocket.....	4 Post...	6	55 200	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28ω
126-A							4 Lead...								
126	F-3	3500F	24	C.	4	Sprocket......	4 Post...	4	55 200	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28ω
126-A							4 Lead...								
126		3502	24	C.	4	Sprocket......	4 Post...	6	55 200	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28ω
126-A							4 Lead...								
123	B-4	3505	24	C.C.	4	Oldham......	5 Post...	6	55 200	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28ω
123	B-4	3505	24	C.C.	4	Oldham......	5 Post...	6	55 200	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28ω
125	D-3	3508	24	C.	4	Oldham......	4 Post...	6	55 200	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28ω
124	D-8	3510	24	C.	4	Flange.......	4 Post...	6	55 200	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28ω
	D-4	3551	16	C.C.	4	Oldham......	4 Lead...	7	44 240	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28ω
	D-5	3552	24	C.	4	Oldham......	4 Lead...	6	55 200	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28ω
126-A	F-5	3550	16	C.	4	Sprocket.....	4 Lead...	7	44 240	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28ω
80-A	D-10	3546	24	C.	4	Sprocket.....	4 Lead...	6	55 200	3 to 4 @ 1250 r.p.m.	−1	.030	.025	2	28ω
841	G-1	3554	12	C.	3.990	Sprocket.....	2 Post...	$7\frac{1}{2}$	36 240	1 to $1\frac{1}{2}$ @ 1000 r.p.m.	−1	.030	No Li	miting	Relay
841	G-1	3555	12	C.C.	3.990	Sprocket.....	2 Post...	$7\frac{1}{2}$	36 240	1 to $1\frac{1}{2}$ @ 1000 r.p.m.	−1	.030	No Li	miting	Relay
841	G-2	3556	24	C.	3.990	Sprocket.....	2 Post...	6	55 220	1 to $1\frac{1}{2}$ @ 1150 r.p.m.	−1	.030	No Li	miting	Relay
841	G-2	3557	24	C.C.	3.990	Sprocket.....	2 Post...	6	22 220	1 to $1\frac{1}{2}$ @ 1150 r.p.m.	−1	.030	No Li	miting	Relay

Replacing Dodge Chain. When the driving chain on any equipment operated in this manner has worn to a point where it no longer makes proper contact with the sprockets (the chain being adjusted to the correct tension), it will be necessary to replace it. While the following instructions for "fishing" the chain through the housing apply particularly to the Dodge car, with little modifications here and there they will be found equally applicable to all similar installations.

Having removed the old chain, pass a short piece of wire through the end of the new chain, Fig. 308. Then start the chain on the lower side of the sprocket, as shown in the illustration, hooking the wire through the sprocket to keep the chain in mesh, and slowly turn the engine over by hand until the chain appears at the top of the sprocket. Then remove the wire from the sprocket, hold the end of the chain, and continue to turn the engine over until the chain is in a position to apply the master link.

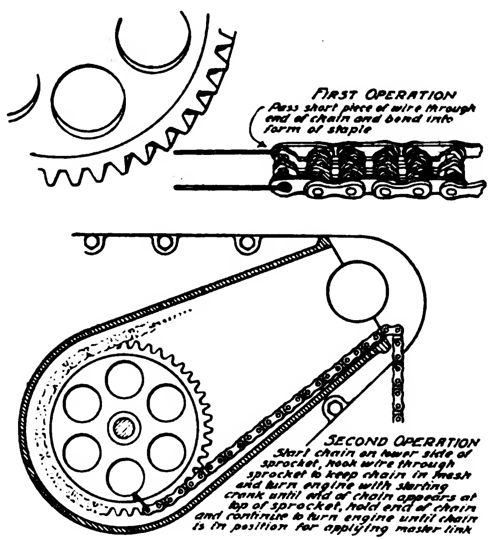


Fig. 308.—Diagram Showing Method of Inserting Chain in North East Equipment on Dodge Cars

Mechanical and Electrical Characteristics. When it is desired to make bench tests of any of the North East apparatus with the aid of the outfit described in connection with the Gray & Davis tests, the data shown in Table V will be found valuable for checking purposes. The left-hand columns give the mechanical characteristics, with the aid of which the unit may be identified, while the right-hand columns give the electrical characteristics, such as the charging rate, torque in foot-pounds with given current input, cutting-in and cutting-out points of the master relay (battery cut-out), air gaps for the limitation relay, and the resistance of the units.

REMY SYSTEM

Six-Volt; Two-Unit; Single-Wire

Generator. Of the multipolar (four-pole) shunt-wound type of generator combined with ignition timer and distributor and designed to be driven at 1½ times crankshaft speed, several models are made, of which one is shown in Fig. 309. In this case, both the regulator for the generator and the battery cut-out are mounted directly on the generator. On some of the models only the regulator is so mounted, the cut-out being placed on the dash of the car, while on others no independent regulating device is required as the third-brush type of regulation is employed (on bipolar generator).

Fig. 309. Remy Ignition Generator and Distributor
Courtesy of Remy Electric Company, Anderson, Indiana

Regulation. In accordance with the model of generator and the requirements of the engine to which it is to be fitted, either the constant-voltage method of regulation using a vibrating regulator mounted on the generator or the third-brush method is employed.

Constant-Voltage Method. The regulator for the generator is similar in principle to that described in connection with the Bijur system. It consists of an electromagnet; two sets of contact points, two of which are mounted on springs; a pivoted armature which may move to make or break the circuit; and a resistance unit. When running at too slow a speed to produce its maximum output, the generator field is supplied with current passing directly through the regulator contact points, which are held together by a spring. As soon, however, as the speed of the generator increases to a point where it tends to cause its output to exceed the predetermined maximum, the charging current which is flowing through the coil of the electromagnet energizes it so such an extent as to cause it to

pull the armature down. This separates the contacts and causes the field current to pass through the resistance unit, thus decreasing the field current and, in turning, decreasing the generator output, which reduces the exciting effect on the electromagnet and causes it to release its armature, cutting the resistance out of the field circuit. The latter immediately builds up again, and the operation is repeated as long as the speed remains excessive for the generator, which is thus supplied with a pulsating current to excite its fields, and its output is held at a practically constant value.

Third-Brush Method. The third-brush method of regulation is based upon the distortion of the magnetic field of a generator at high speeds. When running at low speeds, the magnetic flux of a generator is evenly distributed along the faces of its field pole pieces, but at high speeds there is a tendency to drag it out of line in the direction of the rotation of the armature. It is then said to be distorted. The third brush, which supplies the exciting current to the field winding, is so located with relation to the main-line brush of opposite polarity that this distortion of the magnetic flux reduces the current which it supplies to the fields. This decrease in the exciting current of the field causes a corresponding decrease in the output of the generator, and as the distortion of the magnetic flux is proportional to the increase in speed, the generator output falls off rapidly the faster it is driven above a certain point, so that it is not damaged when the automobile engine is raced.

Thermostatic Switch. More of the current produced by the generator is used for lighting purposes in winter than in summer, in the proportion that the demands for house lighting vary with the change of the seasons. Added to the decreased efficiency of the storage battery in cold weather, this tends to place a greatly increased load on the generator in the winter months. If the generator, as installed, were regulated to produce sufficient current to take care of this maximum demand, it would keep the storage battery in a constant state of overcharge in summer and would be likely to ruin the plates through excessive gassing. The Remy engineers have accordingly developed a method of regulation that will automatically compensate for the difference in the demand with the changing seasons, consisting of a thermostatic switch in connection with the third-brush control; it will be found, among others, on the Reo 1917 models.

To gain a clear idea of the action of an electric thermostat, the heating effect of the current must be kept in mind; also that different metals have different coefficients of expansion, i.e., some will expand more than others under the influence of the same degree of heat. Electric thermostats have been in use for years as automatic fire alarms and as temperature-controlling devices in incubators and for residence heating, and within the past few years they have come into use on the automobile to control the circulation of the cooling water and the suction of the engine in accordance with variations in the temperature. The device consists of a thermal member, or blade, of two different metals riveted together at their ends. This member is held fast at one end and at the other it carries a contact point, designed to complete the circuit by touching a stationary contact. Under the influence of an increase in temperature, one of the metals

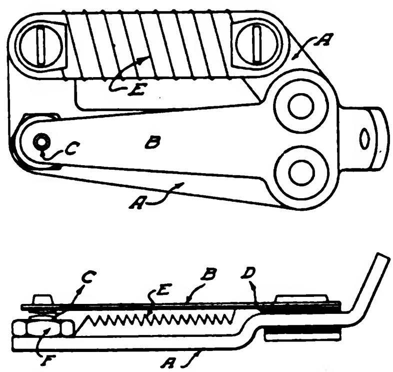


Fig. 310. Details of Remy Thermostatic Switch

Fig. 311. Wiring Diagram of Switch Connections

expands more than the other and thus springs this member, or blade, away from the stationary contact.

The details of the Remy thermostat are shown in Fig. 310. *B* is the thermo-member carrying the silver contact *C*, and is supported on

a strip of steel *A*. *A* also carries the resistance unit *E*, which is a short coil of high-resistance wire wound on heavy mica insulation. *A* and *B* are riveted together at the end *D* so as to insulate them from each other. The two metals composing *B* are spring brass and nickel steel, the strip of spring brass being placed on the lower side of the blade. Sufficient tension is placed on this strip, by means of the adjusting nut *F*, to keep the points firmly in contact at temperatures below 150° F. This adjustment is made by the manufacturer and is permanent.

As shown in the wiring diagram, Fig. 311, which illustrates the relation of the thermo-switch to the third-brush method of regulation, it will be noticed that the switch is placed near the commutator of the generator, as that is the hottest part of the machine when it is in

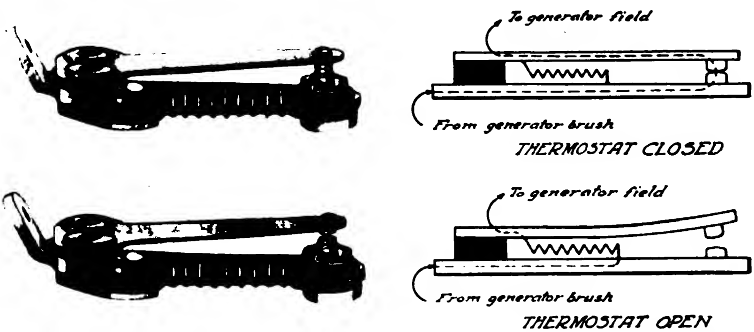


Fig. 312. Photographic Reproductions and Diagrams of Action of Thermostatic Switch When Closed and Opened
Courtesy of Remy Electric Company, Anderson, Indiana

operation. It will be noticed also that when the contact points of the thermo-switch are open, as shown in the illustration, the current supplied to the field by the third brush must pass through the resistance unit of the switch, thus cutting it down. This is the position for warm-weather running, when not so much of the current is required for lighting, and when the storage battery is at its best. When the temperature of the air about the thermo-switch exceeds 150° F., the movable blade is warped upward, owing to the greater coefficient of expansion of the brass as compared with that of the nickel steel. The contact points will accordingly remain open as long as the temperature exceeds this degree. When it falls below that point, the quicker contraction of the brass pulls the blade down, and the points again make contact, cutting out the resistance and increasing the output

of the generator, diagrams of the thermo-switch in its closed and open positions being shown at the right, and a halftone of the switch at the left in Fig. 312, while the curves, Fig. 313, show the increase in the current output brought about by the closing of the thermo-switch points. The path taken by the current when the points are open and when they are closed is indicated by the dotted lines in the diagrams, Fig. 312. The curves show that with the thermo-switch open, the maximum current output of the generator is limited to 14 to 15 amperes, while with the switch closed it rises to 20 to 22 amperes. The switch will normally remain closed after the engine has been idle for any length of time; but in summer it will open after driving a few miles, while in winter it will probably remain closed, no matter how much the car is driven.

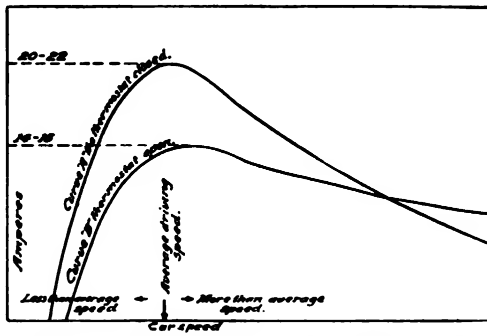


Fig. 313. Output Curves of Remy Patented Generator

Starting Motor. The motor is the 6-volt 4-pole series-wound type, illustrated in Fig. 314, mounted either with gear reduction

Fig. 314. Remy Starting Motor with Outboard Type Bendix Pinion

and over-running clutch, or with automatically engaging pinion for direct engagement with flywheel gear, as described in connection with the Auto-Lite. The latter is known as the Bendix gear. The control is by independent switch.

Instruments and Protective Devices. An indicator, or *telltale*, shows when the battery is charging or discharging, and also serves

to indicate any discharge, in all except the starting-motor circuit, due to grounds or short-circuits. All lamp circuits are fused, and a fuse is inserted in the regulator circuit.

Remy Single-Unit

A Mechanical Combination. While termed a single-unit type, this is actually two independent units combined, *mechanically* and *not electrically*, so that it bears no resemblance to the single unit on which both field and armature windings are carried on the same pole pieces and armature core. The field frame for the two units is a single casting, Fig. 315, but the magnetic circuits of both the generator and the motor are entirely independent, and each is a separate unit. They are combined in this manner solely for convenience in mounting where space is limited. The vibrating type of voltage regulator is employed in connection with the generator, while the starting motor operates through a train of reducing gears and an over-running clutch. Apart from the combination of the two units and the method of starting drive which this entails, the system is the same in its essentials as where the units are mounted independently.

Fig. 315. Combined Field Frame of Generator and Motor for Remy Single-Unit System

Wiring Diagrams. Velie. Fig. 316 shows the installation on Velie, Model 22, and the details will be plain with further explanation. The "ratchet reversing switch", shown in the diagram, is for controlling the ignition current, and it is designed to reverse the direction of this current each time the switch is turned on in order to prevent the formation of a crater and cone on the ignition interrupter contacts, as previously described, thus keeping the points in good work-

IGNITION COIL

COMBINED LIGHTING

Fig. 316. Wiring Diagram for Remy Installation on the Velie, Model 22

ing order for a much longer period. The dash and tail lights are 3½-volt lamps, wired in series, so that the failure of one puts the other out, thus giving an indication at the dash of the failure of the tail light.

Oakland. The Remy installation on Oakland Model 32 is shown in Fig. 317. The chief distinction between this and the previous diagram is the employment of a single 10-ampere fuse on the lighting circuits instead of independent fuses on each circuit. "Breaker box" refers to the ignition-circuit contact-breaker, or interrupter, as it is variously termed. The starting motor in this case is fitted with the Bendix drive.

Reo. On the Reo installation, Fig. 318, the starting motor is mounted on the transmission housing and drives to a shaft of the latter through a worm gear. In this case the starting switch is mounted directly on the starting motor, and an ammeter is supplied on the charging circuit instead of a telltale, or indicator.

National. A typical installation of the single unit, or so-called double-deck unit, is shown in Fig. 319. This is on the National six-cylinder model and is a two-wire system. It is not interconnected with the ignition system, so there are no ground connections, and no fuses are employed.

Instructions. These instructions cover the systems which include the ignition. For instructions applying to the double-wire system on cars having an entirely independent ignition system, like the National, see instructions under Auto-Lite, Delco, Gray & Davis, and others, for failure of generator or motor, short-circuits, and the like.

Battery Discharge. In systems of this type, discharge of the battery may be due to failure to open the ignition switch after stopping the car. The amount of current consumed is small but in time it will run the battery down. The indicator or the ammeter, according to which is fitted, will show a discharge. An entire failure of the current may indicate: a loose connection at battery terminals, at battery side of starting switch in connection with a blown main fuse (Oakland), or a loose battery ground connection; a loose connection at motor side of starting switch or at starting motor, or a broken wire between the switches. (See previous instructions on other makes for testing with lamp set for broken or grounded circuits.)

Fig. 317. Wiring Diagram for Remy Installation on the Oakland, Model 32

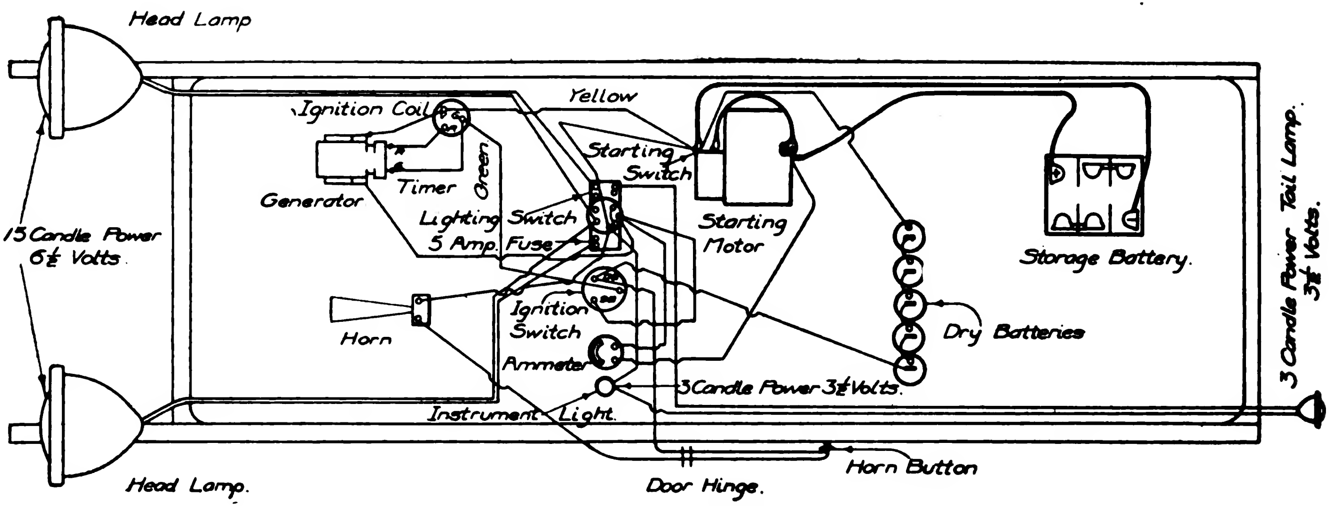


Fig. 318. Wiring Diagram for Remy Installation on "Reo the Fifth"

Fig. 319. Wiring Diagram for Remy Double-Deck Unit on the National Six

Failure of Lighting, Ignition, Starting. When the lights and ignition fail but the starting motor operates, it indicates a short or open circuit between the starting switch and the main fuse (Oakland). This fuse should first be examined and, if blown, a search should be made for the ground or short-circuit causing it, before putting in a new fuse. The fault will be in the wiring between the switch, lights, and ignition distributor. See that all connections, including those on fuse block, are tight. When the lights fail but the ignition and starting motor operate, the trouble will be found either in the circuits between the lighting switch and lamps; in the lamps themselves, as a burned-out bulb causes a short-circuit; or from loose connections in these circuits. Failure of the ignition, with the remainder of the system operating, may be traced to loose connections at the ignition switch, coil, or distributor; poor grounding of the ignition switch on the speedometer support screw; or to open or short-circuits between the ignition switch and the distributor. Further detail instructions on ignition are given in Ignition, Part II.

Dim Lights. When all the lights burn dimly, the most probable cause is the battery, but if a test shows this to be properly charged, a ground between the battery and the starting switch or between the latter and the generator may be responsible for leakage. Other causes are the use of higher candle-power lamps than those specified, the use of low efficiency carbon-filament bulbs, or failure of the generator to charge properly.

Examine generator-field fuse and if blown, look for short-circuits before replacing, as previously instructed. A simple test of the generator may be made by switching on all the lights with the engine standing. Start the engine and run at a speed equivalent to 15 miles per hour or over. If the lights then brighten perceptibly, the generator is operating properly. This test must be made in the garage or preferably at night, as the difference would not be sufficiently noticeable in daylight.

If the generator fuse is intact, examine the regulator relay contacts. If the points are stuck together, open by releasing the relay blade with the finger. Clean and true up points as previously instructed and clean out all dust or dirt from relay before replacing cover. Particles of dirt lodged between the points will prevent the generator from charging properly.

The failure, flickering, or dim burning of any single lamp will be due to a burned-out bulb, to loose or frayed connections at lamp or switch, to a bulb loose in its socket, or to an intermittent ground or short-circuit in the wiring of that particular lamp, or to the frame of the lamp nor being grounded properly. Where dash and tail lamps are in series, examine both bulbs and replace the one that has burned out. Test with two dry cells connected in series.

Ammeter. When the indicator, or ammeter, does not register a charge with the engine running with all the lights out, stop the engine and switch on the lights. If the instrument gives no discharge reading, it is faulty. If it shows a discharge, the trouble is in the generator or connections. In case the ammeter registers a discharge with all the lights off, ignition switch open, and engine idle, examine relay contacts to see if they remain closed. If not, disconnect the battery. This should cause the ammeter hand to return to zero; if it does not, the instrument is out of adjustment. With the ammeter, or indicator, working properly, and the relay contacts in good condition, a discharge then indicates a ground or short-circuit. When examining the relay for trouble, do not change the adjustment of the relay blade.

SIMMS-HUFF SYSTEM

Twelve-Volt; Single-Unit; Single-Wire

Dynamotor. The dynamotor is of the multipolar type having six poles, as illustrated in Fig. 320, which shows the field frame, coils, and poles. Fig. 322 illustrates the assembled brush rigging, while Fig. 321 shows the complete unit with the commutator housing plates removed.

Regulation. Regulation is by reversed series field, in connection with a combination cut-out and regulator. The regulator is of the constant-potential type and is combined with the battery cut-out. It is connected in circuit with the shunt field of the generator, and the vibrating contacts of the regulator cut extra resistance into this circuit when the speed exceeds the normal generating rate. There is also a differential compound winding of the fields, the two halves of which oppose each other at high speeds.

Instruments. An ammeter is supplied, showing *charge* and *discharge.*

Dynamotor Connections. The dynamotor has two connections, one at the bottom of the forward end plate, marked DYN+, and the other on top of the field yoke designated as FILED. As the system is a single-wire type, the opposite sides of both circuits are grounded within the machine itself. The terminals on the cut-out are marked BAT+, DYN+, and DYN−, BAT−, and FLD.

Fig. 320. Field Frame, Poles, and Windings for Simms-Huff Dynamotor

Fig. 321. Brush Rigging for Simms-Huff Dynamotor

Fig. 322. Simms-Huff Dynamotor with Commutator Housing Plates Removed
Courtesy of Simms Magneto Company, East Orange, New Jersey

BAT+ connects through a 12-gage wire to the negative side of the ammeter and thence to a terminal on the starting switch. This connects it permanently to +R of the battery through the ammeter. This wire supplies the current to the distributing panel, from which

current is supplied to the lamps and horn. DYN+ connects through a similar wire to the plus terminal of the dynamo, while DYN− and

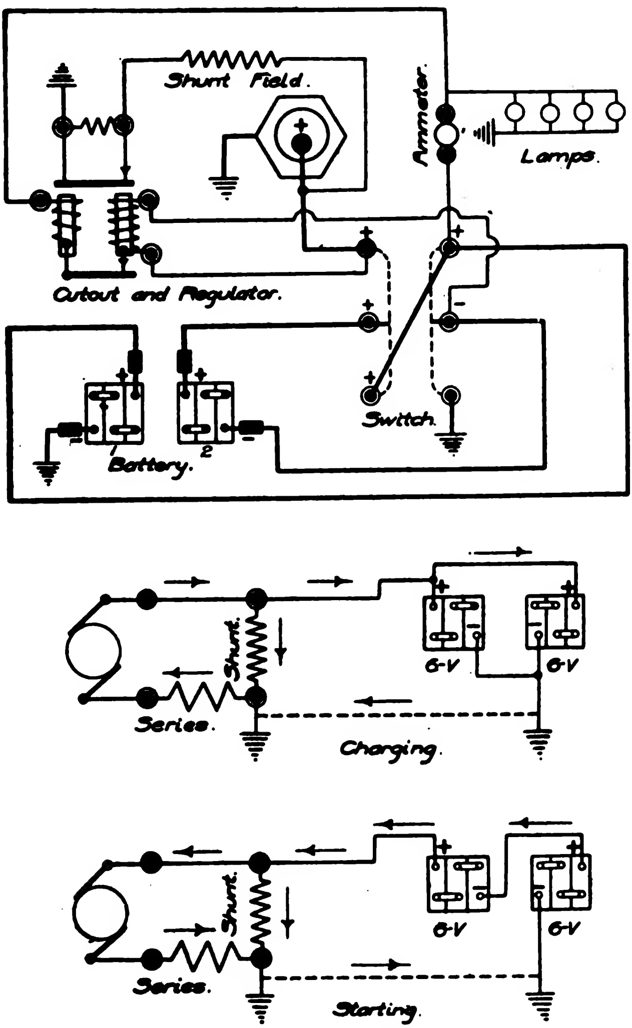


Fig. 323. Wiring Diagram for Simms-Huff Starting and Lighting Systems

BAT− connect with the −L terminal of the storage battery through a wire of the same size.

Change of Voltage. The system is known as 6—12-volt type, signifying that the current is generated at 6 volts, but is employed for

starting at 12 volts. There are accordingly 6 cells in the storage battery, and the latter is charged by placing the two halves of it, consisting of two 3-cell units, in parallel. This is indicated in the

Fig. 324a. Complete Wiring Diagram for 1916-17 Maxwell Cars (see Fig. 324b)
Courtesy of Simms Magneto Company, East Orange, New Jersey

upper diagram, Fig. 323, also in the middle diagram, which shows the connections for charging. In the lower diagram of the figure are shown the starting connections, the switch being connected to throw the 6 cells of the battery in series, so that the unit receives current at

12 volts for starting, thus doubling its power. Six-volt lamps are employed and are supplied with current from the left-hand section of the battery, marked *1*, as shown in the upper part of the diagram.

Fig. 324b. Complete Wiring Diagram for 1916-17 Maxwell Cars, Showing Details of Dash Panel and Batteries
Courtesy of Simms Magneto Company, East Orange, New Jersey

Starting Switch. This is mounted on the left side of the gear-box housing (Maxwell) and is so arranged as to connect the entire battery in series for starting, thus giving current at 12 volts for this purpose. The same movement of the starting switch also puts the

battery in circuit with the ignition system so that, as soon as the engine starts and the switch is released, it automatically disconnects the battery from the ignition, and the engine then runs on the magneto (dual ignition system).

Wiring Diagram. Fig. 324*a* and Fig. 324*b* show the wiring diagram complete of the ignition, starting, and lighting systems as installed on the 1916 and 1917 Maxwell cars. The heavy lines indicate the starting-system connections, while the light lines are the wires leading from the generator to the battery (through the regulator and cut-out), and the various connections for the ignition and the lamps. They show very plainly, upon tracing them out, the relation of the regulator and cut-out to the generator and the battery, as well as the method of dividing the six cells of the battery into two units for lighting service, and the coupling of all the cells in series for starting. It will be noted also that the storage battery is not utilized for ignition, as the starting switch closes the circuit of a dry battery of four cells for ignition when starting the engine. As the starting switch automatically opens this circuit when released, there is no danger of this battery being inadvertently left in circuit.

At the upper left-hand corner of the diagram, complete details of the ignition circuit and of the magneto itself are shown. The magneto (Simms) is of the true high-tension type, having primary and secondary windings on the armature core, as well as a condenser incorporated in it. As this sketch shows not only the relation of high-tension type of magneto to the plugs but also that of the essential parts of the magneto, as well as the relation of the ignition system to the starting and lighting systems through the combination starting and ignition switch, it will repay close study. The number of wires makes it appear as if this were a two-wire system, but upon noting the ground connections at the various terminals it will be evident that it is not.

Instructions. The Simms-Huff system as above described is standard equipment on the Maxwell cars. The combination cut-out and regulator is mounted on the rear of the dash panel carrying the ammeter and switch. It consists of two distinct devices, the cut-out serving the usual purpose of protecting the battery when the generator voltage drops, and the regulator limiting the current output of the dynamo as the engine speed increases. In connection

with it a special regulator switch is provided. This is located on the right side of the dash panel and has two positions, HIGH and LOW, the latter inserting additional resistance in the field circuit of the dynamo to further limit its output when the car is driven steadily at high speed on long runs. This switch is kept in the HIGH position for all ordinary driving and only shifted to LOW as above mentioned.

Failure of Cut-Out or of Regulator. Should the ammeter pointer go to the limit of its travel on the *discharge* side, this indicates that the cut-out contact points have failed to release on the slowing down of the generator. The latter also will continue to run as a motor after the engine is stopped. Disconnect the two wires from the terminals on the generator and wrap them with friction tape to prevent their coming in contact with any metal parts of the car. Clean and true up contact points as outlined in previous instructions. An unusually high reading on the *charge* side of the ammeter will indicate a failure of the regulator to work. If an inspection shows no sign of broken or crossed wires, loose connections, or other obvious trouble, the manufacturers recommend that the unit be sent to them. In the case of the owner, it is recommended that no attempt be made to correct faults in the cut-out or in the regulator, but that it be referred to the maker of the device or to the nearest service station.

Generator Tests. To determine whether a short-circuit or a ground exists in the brush holder, pull up all the brushes and with the aid of the lamp-test set, test by applying one end to the frame and the other to the main terminal post. The lamp will light if there is a short-circuit or a ground between the brush holder and the frame. A similar test may be made for the armature by pulling up all the brushes (or heavy paper may be inserted between them and the commutator) and placing one point on the commutator and the other on the shaft. The lighting of the lamp will indicate that the armature is grounded. In all tests of this nature where the lamp does not light at the first contact, it should not be taken for granted at once that there is no fault. Touch various parts of both members on clean bright metal. See that the points of the test set are clean, that the lamp filament has not been broken, and that the lamp itself has not become unscrewed sufficiently to break the circuit between it and

the socket. A good rule is always to test the lamp itself first; sometimes the connecting plug of the set is not properly screwed into the socket.

While the above test for the armature, if properly carried out, will show whether the latter is grounded or not, it will not give any indication of an internal short-circuit in the armature itself. To determine this, connect the shunt fields and run the unit idle as a motor, with the portable ammeter in the circuit, using the 30-ampere shunt. While running without any load the motor should not consume more than 7 amperes at 6 volts, i.e., using half the battery. Tests for grounds in the shunt field may be made with the lamp-test set, but to determine whether there is a short-circuit in the field, it is necessary to measure the resistance of its windings. If there is neither a short-circuit nor a ground in the field, the resistance of the windings should calculate approximately 6½ ohms on units with serial numbers up to 27,000, and approximately 4.8 ohms on starters above this serial number.

The Simms-Huff is one of the very few, if not the only unit, that is belt-driven as a generator. Its normal output is 10 to 15 amperes; so when the dash ammeter shows any falling off in this rate, with the engine running at the proper speed to give the maximum charging current, the belt drive of the generator should be inspected. If the ammeter reading falls off as the engine speed increases, it is a certain indication that the belt is slipping and that the generator itself is not being driven fast enough. Adjust the tension of the belt and test again. If this does not increase the output to normal, inspect the commutator and brushes, brush connections and springs, etc. See that the brushes have not worn down too far, and if necessary, sand-in. Failing improvement from any of these expedients, inspect the regulator. This should not be adjusted to give more current until every other possible cause has been eliminated; and before making any change in the adjustment of the contacts, see if cleaning and truing them up will not remedy the trouble. If necessary to adjust, do so very carefully, as increasing the current output by this means will also increase the voltage, and if the voltage exceeds the normal by any substantial percentage, all the lamps will be burned out at once. Trouble in the electrical unit itself will be most likely to appear in the brush holder.

Whenever it is necessary to remove the front end plate over the commutator to inspect the commutator or the brushes, be sure that this plate *is put back the same way*, and not accidentally turned round a sixth of a revolution, which would cause the motor to run backward. There is a slot in the front end of this plate to permit the brush holder to be moved backward or forward so as to give the best brush setting as a generator and as a motor. On most of the Simms-Huff units, a chisel mark will be found on each side of the fiber insulator under the main terminal post, indicating the factory brush setting. Checking this brush setting should be one of the further tests undertaken before resorting to adjustment of the regulator. To do this, connect the portable ammeter in the charging circuit (30-ampere shunt) or, if one of these instruments is not available, the dash ammeter may be relied upon.

Run the engine at a speed high enough for the maximum normal output; loosen the brush holder and move very slowly backward and forward, meanwhile noting the effect on the reading of the ammeter; and mark the point at which the best output is obtained. To test as a motor, connect the ammeter in circuit with half of the battery and run idle. Move brush holder backward or forward to obtain best setting point, as shown by the ammeter reading, which, in this case, will be the minimum instead of the maximum. The unit should not draw more than 7 amperes when tested in this manner. If the best points for generating and running as a motor, as shown by these tests, are separated by any considerable distance, a compromise must be effected by placing the brush holder midway between them. If the dash ammeter does not appear to be correct, check it with the portable instrument or with another dash ammeter.

SPLITDORF SYSTEM

Twelve—Six-Volt; Single-Unit; Two-Wire

Dynamotor. Both windings are connected to the same commutator on the dynamotor, which is of the bipolar type.

Wiring Diagram. As the lamps are run on 6 volts, the 6-cell battery is connected as two units of 3 cells each for lighting, and these units are connected in series-parallel for charging, as the dynamotor produces current at 6 volts. The remaining details of the connections will be clear in the wiring diagram, Fig. 325.

Six-Volt; Two-Unit

Control. *Switch.* The starting switch is mounted on the starting motor. This switch automatically breaks the circuit as soon as the engine starts. The starting gear slides on spiral splines on the armature shaft, so that when the engine gear over-runs it, the starting gear is forced out of engagement. This gear is connected

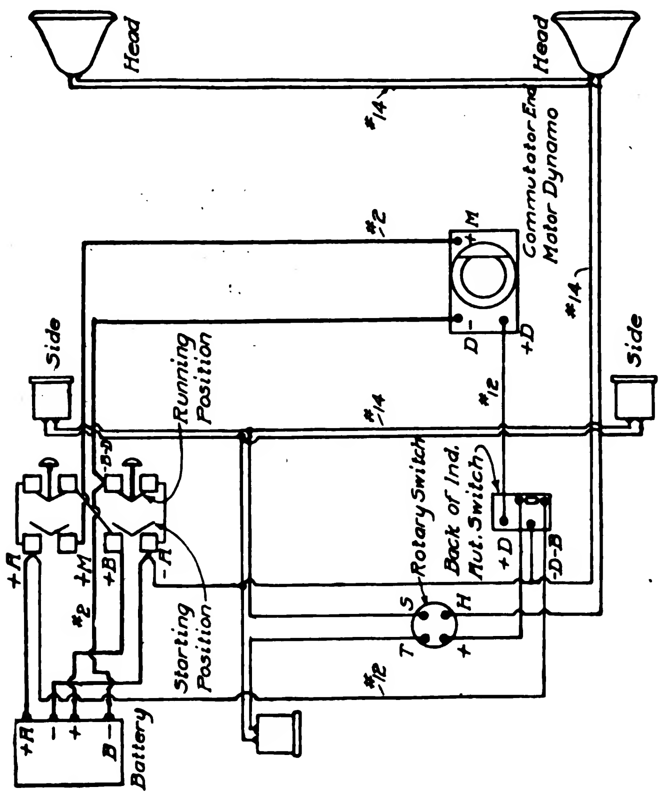


Fig. 325. Wiring Diagram of Splitdorf-Apelco Twelve in Six-Volt Single-Unit Two-Wire System

to a drive rod which also engages a switch rod, so that when the gear is forced out of mesh with the flywheel, it carries the switch rod with it and automatically opens the circuit. The switch contacts cannot stick, and no damage can result from holding down the switch pedal after the engine has started.

Regulation. On the earlier models, a vibrating regulator was built in the generator, as illustrated in the section on Constant-

Potential Generators, but in later models an external regulator combined with the battery cut-out is employed. This is a constant voltage control of the vibrating type, similar to that described in detail in connection with the Bijur system, i.e., an electromagnet operating two spring-mounted armatures carrying contacts.

Instructions. Should a discharge of 3 amperes or more be indicated on the ammeter when the engine is idle and all lights are off, this can be eliminated by slightly increasing the tension of the spring at the rear end of the cut-in armature.

Too great an increase in the tension of this spring will cause the cut-in, or charging point, to be raised too high, as indicated by the ammeter, which should be noted when making the adjustment.

The voltage regulator as set at the factory is adjusted to limit the output of the generator to from 7 to 10 amperes. Should it be necessary to increase this for winter running or for any other reason, it may be done by increasing the tension of the spring armature. The amount of movement of the adjusting screw at the rear end of the armature that is necessary will be indicated by the reading of the ammeter. The passage of current at the regulating contacts, which are in constant vibration while the engine is running above a certain speed, tends to roughen them. In time this may affect the charging rate and cause the points to stick together, which will be indicated by the ammeter showing a permanent increase in the charging rate. If the latter becomes excessive, the cover of the regulator should be removed, and a thin dental file passed between the contacts on the stationary screw R, Fig. 326, and the movable contact on the regulating armature until both become smooth. In case it is necessary to remove the contact screw R for the purpose of smoothing its point, be sure to replace it at the same position, taking care that the ammeter reading does not exceed 7 to 10 amperes and that the lock-nut N is fastened securely. Under ordinary conditions, these con-

Fig. 326. Splitdorf VR Regulator
Courtesy of Splitdorf Electric Company, Newark, New Jersey

tacts should not require attention on an average oftener than once a year, but it would be well to examine them occasionally.

Fig. 327. Wiring Diagram of Splitdorf Lighting Generator and VR Regulator

By referring to Fig. 327, which is a diagram of the wiring of the generator and battery, the relation of these essentials to the regulator and cut-out are made clear. The field fuse shown on this diagram is

also indicated at F in Fig. 326. This fuse is a small piece of soft-alloy wire mounted between the post F and the contact-breaker. By referring to the wiring diagram, it will be noted that this fuse is in the shunt-field circuit, so that if it has been blown, the machine will not generate. It is designed to blow only at high speed with the battery off the line and the vibrator contact R stuck. In actual practice, the regulator cut-out is mounted directly on the generator itself. The colors mentioned alongside the different wires are for purposes of identification so that there will be no mistakes in making the various connections.

Starting Motor. The starting motor is of the series-wound type and is similar in design to the generator. It is supplied with a Bendix drive as shown in Fig. 328.

The starting motor has been designed so that when the operator pushes a foot pedal or pulls a lever, a gear is carried into mesh

Fig. 328. Splitdorf SU Starting Motor
Courtesy of Splitdorf Electric Company, Newark, New Jersey

with a ring gear on the flywheel, and when the engagement is made, current is supplied to the motor. The gear is movably carried on the armature shaft by spiral splines. These splines tend to hold the gear in mesh while the engine is being cranked. As soon as the engine picks up, it turns faster than the motor pinion which is operated with the flywheel, and on account of the spiral splines the pinion is forced out of mesh with the gear on the flywheel. The gear, while being "drivingly" mounted on the armature shaft, is also mechanically connected to a connecting rod, which, as will be noted from the illustration, protrudes from the commutator end of the motor.

The feature of this construction is, that no matter how long the operator may hold his foot on the starting pedal, the current is broken when the engine starts, as in the manner previously described. The

amount of current actually required for turning over the engine is thus controlled by the engine itself, and on account of the positive connection between one element of the switch and the starting gear, all possibility of the jaws of the starting switch sticking is eliminated.

Instructions. Apart from the special adjustments of the starting switch, as mentioned in the description of its operation, the instructions for maintenance are the same as those for other systems. In case this switch does not operate properly, the sequence of operations as mentioned should be checked up, and the distances given verified. In case these distances have become greater through wear, they should be adjusted. To replace the brushes, remove the cover strap over the commutator end of the unit, either generator or motor, put the two screws holding the rocker disc in place, disconnect the brush leads, and withdraw the brushes from the holders. It is important that the brushes slide freely in the holders and that the brush-lead terminals are clean and bright before replacing the terminal screws. See that the springs rest fairly on the ends of the brushes and that their tension has not weakened. Follow instructions given in connection with other systems for care of the commutator.

Failure of Engine to Start. When the starting motor cranks the engine after the starting pedal is depressed but fails to start the engine after a reasonable time, release the starting pedal and ascertain the cause, which may be due to the following: Ignition off, lack of fuel, fuel supply choked, cylinders needing priming due to weather conditions, or cylinders flooded from too much priming.

Should the starting motor fail to crank the engine when the starting pedal is fully depressed, there is a possibility that the battery is run down (which condition will be indicated by an excessive dimming of the lights), that there is a loose connection in the starting circuit, or that the starting switch is not making proper contact. The various tests previously given will probably take care of all these conditions.

Oiling of Starting Motor. The starting motor should be oiled once every 500 miles with any medium high-grade oil by applying oil to the cups, switch rods, guide rods, and pawl; also on the compensating device. Starting motors equipped with the Bendix drive are fitted with oil cups at each end of the unit.

U.S.L. SYSTEM

Twenty-Four—Twelve-Volt, and Twelve—Six-Volt; Single-Unit; Two-Wire

Variations. The 24—12-volt signifies that the starting voltage is 24 and the generating voltage 12, the battery of twelve cells being divided into two groups of six each in series-parallel for charging, while 12—6 signifies that the starting voltage is 12 and the generating voltage 6, the 6-cell battery being divided in the same manner.

The foregoing systems will be found on cars prior to, and including, 1915 models. For 1916 and 1917 models, a 12—12-volt system of the same single-unit two-wire type is standard. In this system the complete battery is used for the lighting as well as the starting, so that charging, lighting, and starting are all at the same voltage, using the complete battery of 6 cells for both of the former.

Generator-Starting Motor. The machine is multipolar (either six or eight poles) and is designed to take the place of the flywheel of

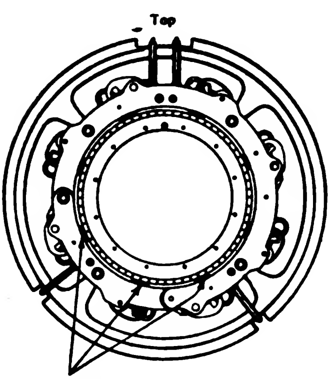
Fig. 329. Details of U.S.L. Flywheel Type Dynamotor with Outside Armature
Courtesy of U. S. Light and Heat Corporation, Niagara Falls, New York

the engine. All but the 12—6-volt equipments are made with an outside armature, Fig. 329, i.e., the armature revolving outside of the field poles which it encloses; and the 12—6-volt with an inside armature, Fig. 330. As the armature is mounted directly on the end of the crankshaft, the drive is direct at engine speed whether charging or starting.

One of the advantages of this type of machine, owing to its large size, is its ability to generate an amount of current far in excess of any ordinary requirement. This permits the employment in the inher-

Fig. 330. U.S.L. Inside Armature Type Dynamotor (External Regulator)

ently regulated type of only three brushes, Fig. 331, when the unit is running as a generator, while all the brushes are employed when it operates as a starting motor. In the types equipped with an external regulator, all the brushes are employed for generating as well as for starting.



3 Generating Brushes

Fig. 331. Location of Generating Brushes in U.S.L. Dynamotor

Regulation. The 24—12-volt unit in the U.S.L. system is made with two types of regulation, one type using an external regulator, which is usually mounted on the dash, and the other of the inherent type. The 12—6-volt type has an external regulator. These two types may be distinguished by the presence of the regulator in the charging circuit, which, however, must not be confused with the automatic switch, or battery cut-out, which is only employed on the inherently regulated type. The details of the regulator are shown in Fig. 332, and it will be noted that the regulator also incorporates the battery cut-out as well as an indicating pointer which shows whether the regulator is working properly or not. In operation, the regulator cuts into the generator field

circuit a variable resistance consisting of an adjustable carbon pile. The connections of the regulator are shown in the wiring diagrams.

The regulation of the U.S.L. inherent type is accomplished by the combination of a Gramme ring armature, a special arrangement of connections and of the field windings, and the use of only a part of the armature and fields for generating. This method is, of course, special on this make and could not be used on other types of construction. The regulation obtained is based on armature reaction and is similar to that resulting from the third-brush method, but the machine

Lower Adjusting Plug

Fig. 332. External Regulator of the U.S.L. System
Courtesy of U. S. Light and Heat Corporation, Niagara Falls, New York

reaches its maximum output at a lower speed than would be possible with the third-brush method and without the employment of a special brush for the purpose.

Instruments and Protective Devices. In addition to the indicator, which is combined with the external regulator in the U.S.L. type, an ammeter is also employed to show the rate of charge and discharge.

Two fuses, mounted in clips on the base which holds the battery cut-out, or automatic switch, protect all the circuits. The smaller of these is a 6-ampere fuse and is in the field circuit of the generator, while the larger is a 30-ampere switch and is in the generator charging circuit. This applies only to those inherently regulated equipments fitted with a special type of automatic switch.

Wiring Diagrams. Figs. 333, 334, and 335 show the standard wiring diagrams of the three types mentioned, being, respectively, the 24—12-volt externally regulated type, the 12—6-volt external regulator and internal-armature type, and the 24—12-volt inherently regulated type. In the diagram proper of each of the 24—12-volt types is indicated the layout for using 7-volt lamps, while the extra diagram at the side shows the method of connecting for 14-volt lamps. The "touring switch" shown on the first two diagrams is a hand-operated switch in the charging circuit and is designed to prevent overcharging of the battery when on long day runs. The inherently regulated type requires very little field current, and on most of these the touring switch is of the miniature push-button type, like a lighting switch.

Instructions. *Touring Switch.* On the types equipped with the touring switch, this enables the driver to control the charge. Pulling out the button closes the switch and permits the generator to charge the battery when the engine reaches the proper speed; pushing it in opens the circuit. This switch must always be closed before starting the engine, and it must be kept closed whenever the lights are on and also under average city driving conditions where stops are frequent and but little driving is done at speed. When touring, the switch should be closed for an hour or two and then allowed to remain open during the remainder of the day, as this is sufficient to keep the battery charged, and there is no need for further charging until the lamps are lighted. The best indication of the necessity for opening the touring switch is the state of charge as shown by the hydrometer. The driver should not start on a long day's run with the battery almost fully charged, without first opening the touring switch, as the unnecessary charging will overheat the battery. This switch should be inspected at least once a season. Push in the button to open the circuits, remove the screw at the back and take off the cover. The switch fingers should be bright and make good contact with the contact block; if they do not do so, remove and clean them, as well as the contact pieces on the block. Do not allow tools or other metal to come in contact with the switch parts during the operation, for even though the switch is open, a short-circuit may result; then one of the fuses will blow. In replacing the fingers, bend sufficiently to make good firm contact.

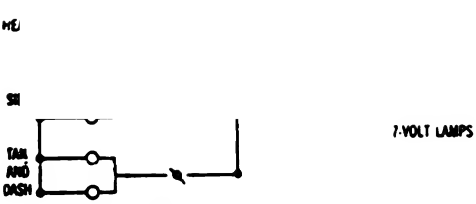


Fig. 333. Wiring Diagram for 24—12-Volt Regulator Type, U.S.L. System

7-VOLT LAMPS

Fig. 331. Wiring Diagram for 12—6-Volt External Regulator Type, U.S.L. System

14-Volt Lamps 7-Volt Lamps

Fig. 335. Wiring Diagram for 24—12-Volt Inherently Regulated Type, U.S.L. System

Starting Switch. The starting switch is filled with oil, and this should be renewed once a year. To do this, the switch must be disconnected, and the screws *A*, Fig. 336, removed; in case the box sticks, insert a screwdriver point between the top of the box and the bottom of the frame and pry loose. To guard against the switch dropping when these screws are removed, hold the hand beneath it while taking them out. Before attempting to remove the switch, disconnect the positive battery connections *B1+* and *B2+* at the battery as shown in Fig. 335. These are the two main terminals in the center. It is unnecessary to tape them, as a short-circuit cannot occur. Pour out the old oil, clean out thoroughly with gasoline, allow to dry, and refill with transformer oil or light motor oil to the proper level with the switch box standing plumb. The proper height on the Type E-2 or E-3 box is $1\frac{5}{8}$ inches, on E-4 box $2\frac{3}{4}$ inches. Before putting in the new oil, however, the drum and finger contacts should be examined, and, if pitted or dirty, should be cleaned with a fine file. Make sure that all fingers bear firmly against the drum so as to make good contact; if they do not, remove and bend them slightly to insure this. If the starting switch is abused in operation, or if improper oil containing water or other impurities be used, the contacts will burn and fail to make good electrical connection. The switch box is the only place in the system requiring oil.

Fig. 336. U.S.L. Oil-Filled Starting Switch

Brush Pressures. There is only one adjustment on the generator, viz, the tension of the brush fingers. The brushes should fit freely in their holders so as to transmit the full pressure of the spring against the commutator. The adjustment as made at the factory should not need correction under one or two years of service. Pressures required on the various machines are as follows: for Type E-12 external regulator, $1\frac{3}{4}$ pounds on each brush; $1\frac{1}{4}$ pounds on brushes of all other external-regulator machines; $1\frac{3}{4}$ pounds on each of the three lowest brushes on the inherently regulated type, these being the only brushes used in generating the charging current; $1\frac{1}{4}$ pounds on each of the remaining brushes of the inherently regulated generator. Keep commutator clean, as the chief cause of

failure of the inherently regulated type is an excess of oil or dirt or both accumulating on it.

Radial and Angular Brushes. The brushes employed are of two types—radial and angular. Radial brushes are used on external-regulator type generators other than those having "Type E-49" on the name plate; angular brushes are used on Type E-49 and all inherently regulated generators. Each radial brush should bear squarely against that side of its holder toward which the commutator rotates. Each angular brush should bear squarely against that side of its pocket away from which the commutator rotates. To sand-in old brushes or fit new brushes properly, insert a strip of No. 00 sandpaper (never use emery, paper, or cloth), between the commutator and the brush, press down on top of brush and draw sandpaper under it, Fig. 337. If the brush is *radial*, draw the sandpaper in the direction of commutator rotation; if *angular*, draw the sandpaper in the direction opposite to that of commutator rotation. No oil is needed on the commutator as the brushes themselves contain all the lubricant necessary.

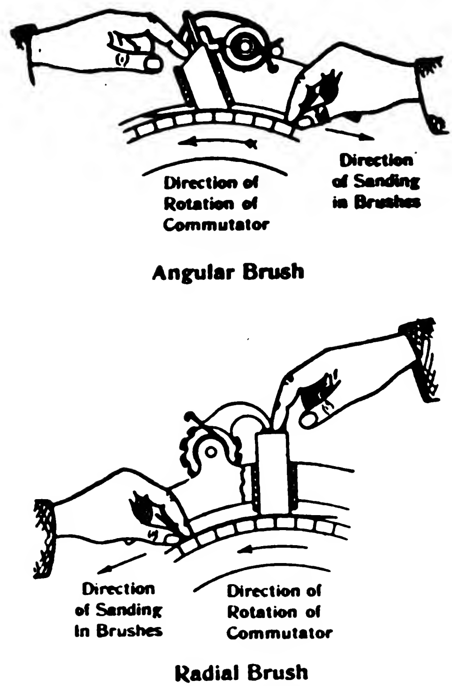


Fig. 337. Methods of Sanding-In Brushes on Dynamotor

Fine sandpaper, as mentioned above, may be used for cleaning the commutator when necessary, the engine being allowed to turn over slowly during the operation.

External Regulator. Should the automatic-switch (cut-out) member of the regulator remain closed with the engine stopped, start the engine at once, and the switch lever should open. If it does not, remove the regulator cover (with the engine running) and

pull the lever open by hand. When the switch lever is correctly set, a slight discharge will be noted on the ammeter the moment the switch lever opens. This discharge reading should not exceed 4 amperes; if in excess of this, increase the tension of the switch-lever spring by releasing the lock nut on the left side of the plate and turning up on the nut at the right until the proper adjustment is secured, then retighten the lock nut. The indicating pointer is moved by the switch lever in closing, and when it appears in its upper position through the sight glass on the cover, the battery is charging; when the switch lever opens, the pointer drops against its stop by gravity.

When the battery shows a lack of capacity, the battery itself and all connections and fuses being in good condition, note the amount of charging current indicated by the ammeter. If the maximum current (external-regulator type) shown by the ammeter does not exceed 10 to 12 amperes at full engine speed after the engine has been running for fifteen minutes, see that the brushes and commutator are in good condition—wipe off the commutator with a dry cloth, and, if necessary, sand-in the brushes to a good seat. If this does not increase the generator output as shown by the ammeter, test the latter as already noted, i.e., see whether the pointer is binding and, if not, check with the portable testing instrument or another ammeter of the dash type. Should none of these remedies correct the fault, *screw in* the lower adjusting plug of the carbon-pile lever slowly, noting the effect on the ammeter reading as the adjustment is made.

With the external regulator, the charging current should not exceed 18 amperes at the highest engine speed. If, at any time, the ammeter shows a higher reading than this, *screw out* the lower adjusting plug of the carbon-pile lever slowly to decrease the current, stopping when the indication does not go above 18 amperes at full speed.

After making this adjustment of the lower plug, make sure that the carbon-pile lever air gap does not exceed $\frac{1}{8}$ inch, and is not less than $\frac{3}{32}$ inch when the engine is stopped. If the gap is too small the switch lever will vibrate rapidly at high engine speeds. When necessary to adjust this gap, screw the upper adjusting plug in or out, but, after doing so, the current output must be checked and adjusted by means of the lower adjusting plug. Always tighten

the adjustment clamping screws after setting either of the adjusting plugs.

Testing Carbon Pile. If the automatic-switch unit of the generator does not cut in with the engine running at speed equivalent to 10 to 14 miles per hour, test the carbon pile by short-circuiting the terminals $F+$ and $A+$ of the generator with the blade of a screw-driver. Speed up the engine slowly and note whether the generator cuts in much sooner than when the terminals are not short-circuited. Do not run the engine at high speed, nor for any length of time with the terminals short-circuited, as an excessive amount of current would be generated. If the generator does cut in much earlier with the terminals short-circuited than without this, the carbon pile needs cleaning. Should the generator not cut in earlier or should it fail to operate altogether, when the carbon pile is short-circuited the trouble is probably in the brushes of the generator or in the touring switch.

To clean the carbon pile, proceed as follows: Unscrew the plug at the upper end of the glass rod and remove the rod; if any of the discs are pitted or burned, rub them together or against a smooth board to make them smooth and flat. Remove the end carbons and clean the brass plates with fine sandpaper, if necessary. In replacing end carbons, make sure that they fit firmly against the brass end plates and that the screw heads do not project beyond the faces of the carbon discs. After reassembling the carbon pile, the regulator will need adjustment for current output, as previously noted.

If for any reason it becomes necessary to disconnect the battery, either open the touring switch and block it open so that it cannot be closed accidentally if the car is to be run, or disconnect and tape the right-hand regulator terminal $A+$. Otherwise, the machine will be damaged by operating.

Battery Cut-Out. Should either of the fuses mounted on the automatic switch of the inherently regulated type blow, immediately open the touring switch. A loose connection or a short-circuit is probably the cause, and the touring switch should not be closed again until the cause has been located.

Ammeter. The ammeter should be checked at least once a year by comparing it with a standard instrument, such as the portable outfit mentioned previously, or any other suitable low-reading ammeter

of known accuracy. To do this, disconnect the positive wire from the ammeter on the dash and connect it to the positive terminal of the standard ammeter used for testing; then connect a wire between

Fig. 338. Wiring Diagram of U.S.L. System on 1917 Mercer Cars

the negative terminal of the standard ammeter and the positive terminal of the dash ammeter. With the engine running at various speeds, take simultaneous readings of both instruments; any differ-

ence between the two should be taken into consideration thereafter when reading the dash ammeter. Unless a test of this kind is carried out, the battery may be receiving either an insufficient or an excessive charge while the ammeter indicates the proper amount.

U.S.L. 12-Volt System. The U.S.L. 12-volt system generates and starts at 12 volts and is standard on the 1916 and 1917 models of the Mercer, Fig. 338. It differs from the other systems in having a magnetically operated starting switch and a centralized control unit, which incorporates all the controlling devices of the entire system, the cut-out, the ammeter, fuse blocks for generator and lighting circuits, starting switch, touring switch, head, side, and tail-light switches, all of which are operated by push buttons. All of these switch buttons, as well as the fuses, are locked in place, while the buttons may be locked in any desired combination of positions.

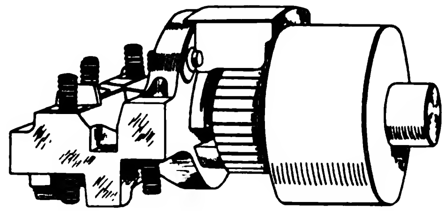


Fig. 339. U.S.L. Type E-14 Starting Switch

Starting Switch. This is of the magnetically operated type and is mounted on the top of the field-mounting frame. It operates by means of a solenoid and plunger, as illustrated in Fig. 339. Control is by means of a spring push button on the control unit marked "start", Fig. 340. When this button is pushed in, it energizes the solenoid of the starting switch, which causes the plunger to close the contacts. Releasing the button on the control unit breaks the circuit, and the switch itself is then opened automatically by a self-contained spring. With this method of control, the current is only on as long as the starting button is held in.

Fig. 340. U.S.L. Control Panel as Mounted on Dash of Mercer Cars

Fuse Blocks. There are two of these, the smaller, illustrated in Fig. 341, being the generator fuse block. This contains only two

fuses, a large one *9* of 30-ampere capacity in the generator-battery charging circuit, and a smaller one *8* of 5-ampere capacity in the generator shunt-field circuit. Should either fuse blow, immediately push in the touring-switch button, as a short-circuit or an open or a loose connection is probably the cause. After locating the trouble, remove the generator fuse block from the instrument board. To do this, unlock the knob, press it inward, and turn $\frac{1}{4}$ revolution to the right or to the left. Replace with spare fuses carried in the light fuse block, return the generator fuse block to its original position, and lock.

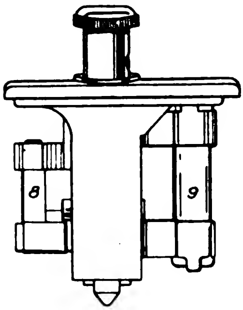


Fig. 341. U.S.L. Generator Fuse Block

The light fuse block, which is shown in Fig. 342, carries a total of seven fuses, of which four are in active use, while the remaining three are spare fuses for use in replacing blown fuses. On the right-side view of this fuse block there appear two large fuses *6* and *7*. Fuse *7* is a protecting link in the ground-return wire of the lighting and horn circuits. The small fuse *5* is of 10-ampere capacity and, together with

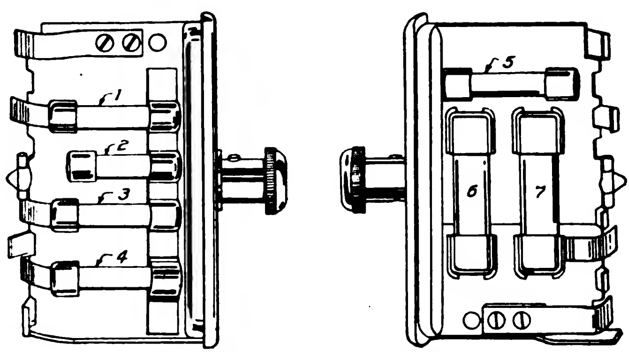


Fig. 342. U.S.L. Left-Hand Side and Right-Hand Side Light Fuse Blocks

fuse *6* of 30-ampere capacity, is a spare fuse for emergency use. On the left side of the block are three active fuses *1*, *3*, and *4* of 10-ampere capacity; and one spare fuse *2* of 5-ampere capacity. Fuse *1* is in the horn circuit, fuse *3* in the headlight circuit, and fuse *4* is common to the tail-, dash-, and side-light circuits. Should any of the fuses on this block blow, the trouble is probably a short-circuit on the frame of the car which should be remedied before the fuse is replaced. Instructions

for the use of the touring switch in this system are the same as previously given.

U.S. Nelson System. This type has been specially designed for the Nelson car, which first appeared in 1917, and it differs radically from those already described in that it is carried on the forward end of the engine crankshaft instead of at the rear. The brushes bear on the inside face of the commutator and may be reached through three openings in the armature support. To clean the commutator in this type, it is necessary to turn the armature so that three of the six brushes appear opposite these openings. Fold a small piece of sandpaper into a square over one of the brushes and allow the engine to turn over for a few minutes. Stop the engine and remove the sandpaper through one of the openings. The engine carries a flywheel at the rear, as usual, and this provision of flywheel weight at both ends of the crankshaft is said to minimize vibration almost to the vanishing point while making possible extremely high speeds.

WAGNER SYSTEM

Twelve-Volt; Single-Unit; Two-Wire (Early Model)

Dynamotor. The bipolar-type dynamotor has both the series and the shunt-windings, i.e., of generator and motor, connected to the same commutator. It is driven direct as a generator, and through a special planetary gear when operating as a starting motor.

Regulation. The regulation is of the inherent type, utilizing the generator winding to weaken the field with increase in speed, i.e., a bucking coil.

Wiring Diagram. *Single-Unit Type.* The left side of the lower half of the diagram, Fig. 343, illustrates the connections when the unit is being used as a starter, as indicated by the arrow showing the direction of rotation of the armature. Those at the right are the running connections, the armature then rotating in the reverse direction and generating current to charge the battery.

Control; Transmission. *Switch.* This is a special type of drum switch mounted directly on the dynamotor on the same base with the battery cut-out. As shown in Fig. 344, when the lever Q is thrown to the left for starting, it also serves to tighten the brake band on the planetary gear. When moved in the opposite direction, it releases this brake, and another set of contacts on the drum of

the switch connect the generator for charging. Fig. 345 shows the details of this switch: *A*, *B*, and *C* are the contacts on the starting side, while *H*, *G*, and *F* are the running-position contacts, as shown in Fig. 343. The segments *E* and *L* on the drum contact with

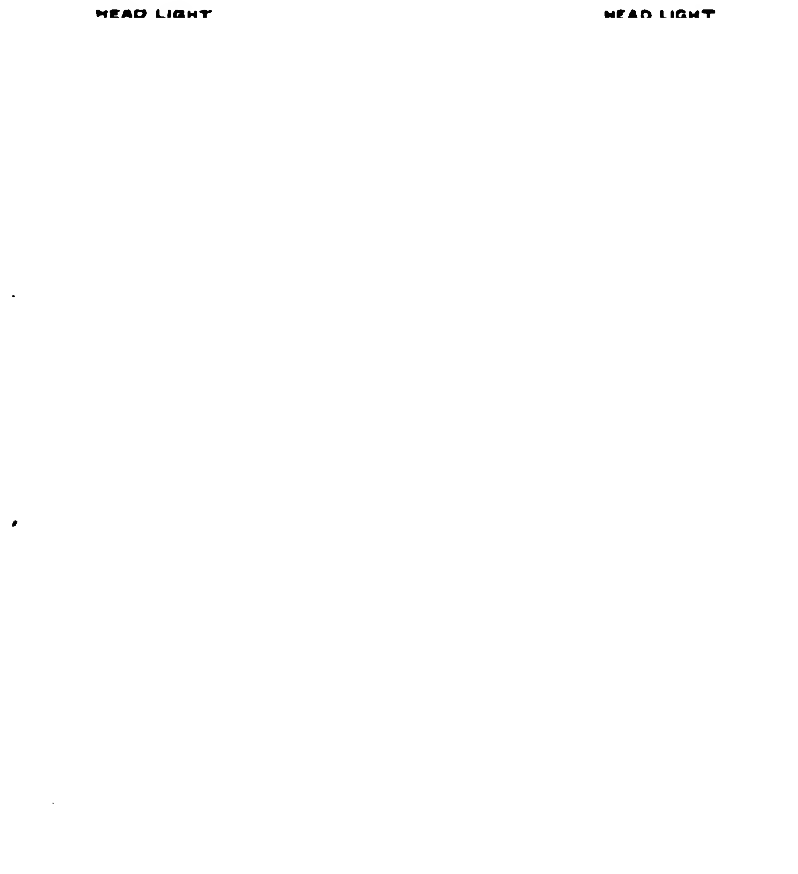


Fig. 343. Wiring Diagram for Wagner Twelve-Volt Single-Unit Two-Wire System (Early Model)

the fingers mentioned when the drum is revolved part way in either direction by the lever, shown at the right, which engages the shaft *M*.

Battery Cut-Out. This is of conventional design. For description and explanation of operation, see previous systems in which a battery cut-out, or automatic switch, is employed. Methods of locating trouble are given in connection with instructions farther along.

Fig. 344. Wagner Control Switch of Drum Type. A—Starter Frame; B—Switch Support; C—Outside End Plate Gear Box; D—Return Spring; F—Oil Hole Screw; G—Self-Closing Oiler; H—Oil Plug; J—Connecting Rod; K—Brake Band; M—Battery Leads; N—End Plate Screws; O—Back End Plate Shield; Q—Starting Switch Lever; R—Brake Band Lever; S—Front End Plate Shield

Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

Fig. 345. Exploded View of Drum Switch. A, B, F, G, H, and K—Contact Screws to Contact; C—Auxiliary Contact Finger; E—Drum Contact; J—Screw Holding C; L—Auxiliary Drum Contact; M—Shaft

Planetary Gear. The external form of the different gear boxes used on the early-model single-unit Wagner starter is the same, but

A

Fig. 346. Exploded View of Planetary Gear Transmission. A—Planetary Pinion; B—Rolling Pawl; C—Center Pinion; D—Planetary Hub; E—Pawl Seat; F—Pawl Plunger; G—Internal Gear; H—Inside End Plate; J—Outside End Plate; K—Oil Plug; M—Sheet-Steel Disc

Fig. 347. Assembled Planetary Gear. Letters same as Fig. 346

their internal construction differs somewhat. The details of the two types employed are shown in Figs. 346 and 347. The principle employed is that of the planetary gear as used to obtain first,

or low, and high speeds on early-model light cars. The unit consists of a central, or sun, gear *C*, Fig. 347, and three planet pinions *A* meshing with the central gear and also with the internal gear ring *G*. For starting, the tightening of the brake band on the outer groove of the internal gear holds it fast, so that the drive is through the central gear and the reducing pinions in engagement with it and the gear ring, while, for running, the rollers *B* in the clutch *D* lock the gears together so that when generating the gear revolves idly as a unit.

Instructions. The instructions previously given in connection with other systems apply here. For failure to generate, lack of capacity, grounds, or short-circuits in windings, and for keeping the

Fig. 348. Jig for Holding Armature and Tooling Commutator

commutator and brushes in condition, see instructions already given, as well as Summary of Instructions at the end of Part VIII.

Method of Tooling Commutator. A different method of undercutting the mica of the commutator is recommended from that already described in connection with the Delco system. This is illustrated in Fig. 348. The armature is removed from the generator and mounted in a simple jig, as shown. The jig is made of 1-inch oak, while ordinary machine screws held in place by lock nuts are utilized as the centers. The bar, or guide, on which the cutter operates, can be made of $\frac{1}{2}$-inch rolled-steel rod, while the cutter itself should be made of $\frac{1}{4}$-inch drill rod. The point of this cutter is ground sharp, like the parting tool used on a lathe or planer, to the thickness of the mica between the commutator bars. The cutter is moved backward and

forward on its guide in the same manner as a planer or shaper tool, and the armature is rotated one segment at a time to bring the mica sections under the tool successively. Where there is not sufficient work of this nature to make it worth while to build the jig, a simple hand tool may be used, Fig. 349. This can be made of a discarded hacksaw blade or a new one, about 8 inches long. One of the ends is ground similarly to the cutter described for the jig, while the other should be shaped like a hook, having the same kind of point as the cutter end. Around the center of this tool should be folded a piece of heavy tin (sheet iron) and the whole wrapped with electric tape. This will prevent the brittle saw blade from breaking and make it much easier to handle. The mica is removed by forcing the sharp end of the tool from the outer edge of the commutator surface to the inner edge, and the rough cut thus made is finished by drawing the hooked end of the tool back through the groove in the opposite direction. To do the job properly, the armature should be held in a vise, otherwise it is liable to move, or the tool is liable to slip, and the copper be cut away with very poor results. Fig. 350 shows the commutator before and after undercutting the mica.

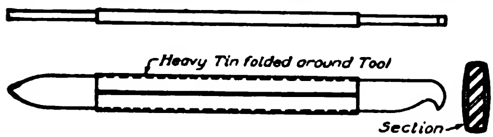


Fig. 349. Diagram of Simple Hand Device for Tooling Commutator

A needle-pointed tool should never be used, as it will simply, make a V-shaped cut in the mica, removing too much in depth and not enough in width. The mica must be cut out clean and square, and a small magnifying glass should be used to see that all of the pieces adjacent to the bars have been removed. After removing the mica, the armature should be placed in a lathe, and a light cut taken from the commutators, i.e., just enough to remove all roughness

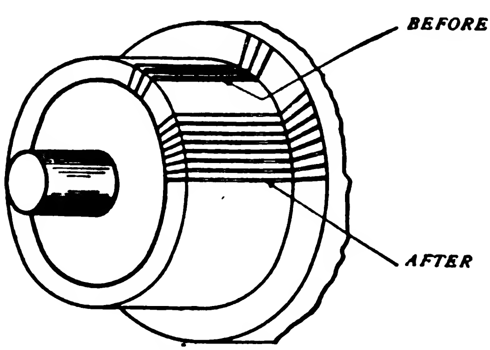


Fig. 350. Diagram Showing Commutator Sections before and after Tooling

and flat spots. The cutting tool employed should be very sharp, so that the soft copper will not be dragged from one segment to another. After turning, fine sandpaper should be used to smooth the commutator. Whether the brushes are replaced with new ones or the old ones are retained, they must be sanded-in to the commutator (see Delco instructions). The springs also should be tested for tension; they must never be allowed to become loose enough to permit the brushes to chatter when the generator is running, as this would interfere seriously with its output.

Lack of Capacity through Faulty Gear Box. Should the battery not charge properly, note whether in starting the lights brighten

Fig. 351. Method of Pulling Wagner Gear Box with a "Come Along"
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

perceptibly with the car running below 5 miles per hour, while at high speed they remain dim. This indicates that the brake band of the gear box does not release, owing either to improper adjustment of the tightening screw or to something getting between the band and drum. To remedy, the band adjusting screw should be turned until the band feels free when the starting lever is in the running position. If something has caught between the band and the drum, its removal usually will be the only remedy necessary.

Should the battery show signs of exhaustion, and if there is no noticeable increase in the brightness of the lamps when the car reaches a speed of 10 miles per hour or its equivalent, the trouble

probably is in the gear box. Remove the front end plate and note if the commutator is rotating. If not, and the reason therefor is not apparent on an inspection of the gears, it may be necessary to remove the gear box. A "come along", such as is employed for taking off Ford wheels, is necessary for this, Fig. 351. It may be found that some of the parts need replacement, or that an entirely new gear box is necessary.

Failure Due to Battery Cut-Out. If the failure to charge the battery be not due to the gear box, remove the cover of the cut-out and see if it is operating properly. When the engine is running at a speed equivalent to 15 miles per hour, the contact should spring away from the adjusting screw. If it does not, connect a voltmeter across the terminals *B* and *H* of the switch, Fig. 352. Should the voltmeter needle not move, examine the contact fingers connected to the studs *C* and *F* and see that they make firm contact with the drum of the switch. Place the end of a pencil on the contact finger *D* and bear down lightly; if the main contact maker then springs away from the adjusting screw, the cause of the trouble is an open circuit at this contact. Bend *D* so that it bears down on the drum segments; should the contacts not close on making this test, the trouble will be an open connection, either in the generator itself or between the generator and the cut-out (switch).

Fig. 352. Details of Wagner Starting Switch. A and B—Large Contact Finger; C—Auxiliary Contact Finger; D—Auxiliary Contact; E—Drum Switch; F, G, and H—Drum Switch Studs; J—Screw Leading to C; Q—Starting Switch Lever

Should the voltmeter give a reading of 6 volts while the contacts do not close, it shows that the shunt coil of the cut-out is open and indicates that its connections are broken or that the trouble is in the coil itself. This may be confirmed by operating the contacts by hand—pushing the contact away from the adjusting screw until it touches the stationary contact. If it remains in that position, the generator is charging the battery, but the shunt coil of the cut-out is out of action and the cut-out will function automatically as it should.

If, under the conditions mentioned in the first paragraph under this heading, the cut-out closes, connect the voltmeter as described and accelerate the engine to a speed corresponding to 25 miles per hour. If the reading is then 15 to 20 volts, the trouble may be looked for in a break in the generator connection to the cut-out. Should it not be possible to locate any break, it may be in the series coil of the cut-out, in which case a new cut-out will be necessary.

Switch or Generator Parts to Be Adjusted. If the starting lever of the switch is not returning to the proper position for running after starting the engine, it will be indicated by a low battery and dim lights. Adjust so that the lever will go to correct position for running and see that the contact fingers of the switch are making proper contact with the drum.

In case the battery does not get sufficient charge, connect an ammeter to the terminal *D* of the switch and to *W* of the cut-out. At a speed equivalent to 15 miles per hour, the ammeter should read 7 to 9 amperes if the generator is working properly. If it does not, examine the commutator, brushes, and wiring, as previously described.

Six-Volt; Two-Unit

General Characteristics. This type is similar in characteristics to most of the other makes of this class already described.

Generator. The generator is the multipolar (four-pole) shunt-wound type.

Regulation. The regulation is of the inherent or bucking-coil type, integral with the field windings of the generator.

Starting Motor. The motor is four-pole and series-wound, driving through a reducing gear mounted on the motor housing, Fig. 353.

Control. *Battery Cut-Out.* The complete instrument, minus its cover, is shown in Fig. 354. It is of standard design and is intended

to be mounted in the tool box under the driver's seat. As shown in the photograph, the upper binding post is the series-coil connection, the central binding post just below it is the shunt-coil connection,

Fig. 353. Wagner Six-Volt Two-Unit Type Starting Motor. Left—Commutator End; Right—Gear End
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

while the lowest binding post is a connection completing the circuit through both coils to the battery.

Switch. The switch is of the circular knife-blade type, two sets of spring contacts close together being pressed down over the stationary contact against the spring, as shown in Fig. 355 which illustrates the parts of the switch.

Fig. 354. Wagner Cut-Out

Wiring Diagram. A typical wiring diagram of the Wagner two-unit system as installed on the Scripps-Booth four- and eight-cylinder models is shown in Fig. 356. The only difference in the wiring of the two models has to do with the ignition and merely affects the distributor connections, as illustrated by the panel in the upper right-hand corner, which shows the distributor and connections for the four-cylinder car. As the system is a single-wire type, one side of every circuit is grounded, the spark plugs themselves representing the grounded side of the high-tension ignition

circuit. The caution on the diagram—*Never run generator with battery removed from car nor with wire disconnected from generator*—applies not only to the Westinghouse system but to practically every other system as well.

Instructions. *Ground in Starting or in Lighting Circuits.* When the blowing of a fuse on one of the lighting circuits is due to a ground, or a similar fault is suspected in the starting system, it may be tested for either with the lamp outfit already described or with the low-reading voltmeter, as follows:

Disconnect one battery terminal, taping the bare end to prevent contact with any metal parts of the car, and connect one side of the voltmeter to this terminal. Attach a length of wire having a bared end to the other terminal of the voltmeter, as shown in Fig. 357.

Fig. 355. Details of Wagner Switch
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

Connect the bared end of the free wire to some part of the car frame; making certain that good electrical contact is made. Disconnect the generator and starting motor completely, open all lighting switches, and be sure that ignition switch is off. If there is no ground in the circuit, the voltmeter will give no indication. Be sure that none of the disconnected terminals is touching the engine or frame; to insure this, tape them.

Should the voltmeter give a reading of 4 volts or more, it indicates that there is a ground in the wiring between the battery and the junction box, or in the wiring between the junction box and the generator or the starting motor. If the voltmeter reads less than 4

volts but more than ½ volt, all wiring and connections should be carefully inspected for faults. This test should be repeated by reversing the connections, that is, by reconnecting the wires on the side of the battery circuit that has been opened and disconnecting the other side.

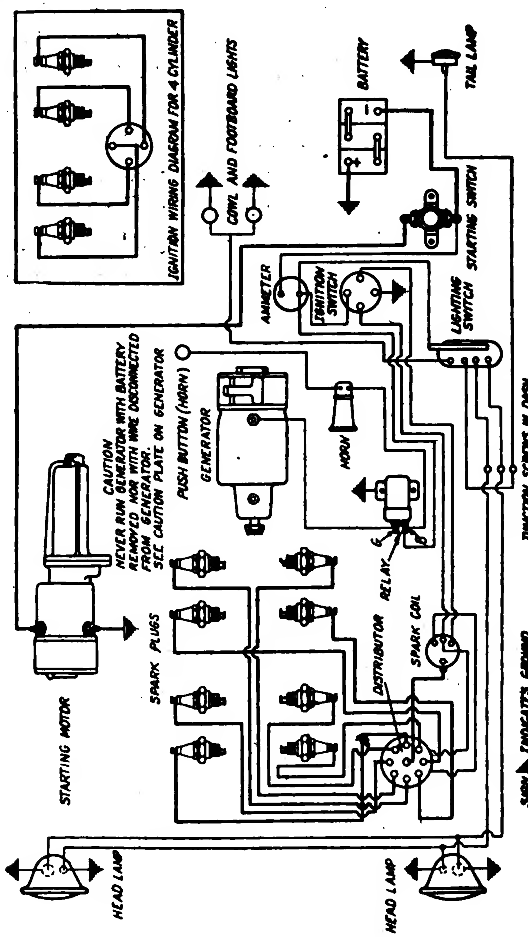


Fig. 356. Wagner Two-Unit System for Scripps-Booth Four- and Eight-Cylinder Models

Localizing Any Ground. To localize any fault that the reading of the voltmeter may show, reconnect the wires to the starting motor and close the starting switch; any reading of the voltmeter with such connections will indicate that the ground is in this circuit. Should no ground be indicated with these connections, disconnect

the starter again and reconnect the generator; if the voltmeter records any voltage, the ground is in the generator circuit. With both starter and generator disconnected, the voltmeter being connected first to one side of the battery and then to the other, operate the lighting switches, the ignition switch, and the horn, one at a time, and note whether the voltmeter needle moves upon closing any of these switches. A voltage reading upon closing any of these switches will indicate a ground in that particular circuit.

Fig. 357. Testing for Grounds with Voltmeter in Two-Wire System

Short-Circuit Tests. To test for short-circuits, substitute the ammeter for the voltmeter, but do not connect the instrument to the battery. The shunt reading to 20

Fig. 358. Testing for Short-Circuits with Ammeter in Two-Wire System

amperes should be employed, one side of the ammeter being grounded on the frame as previously described, and the other being connected with a short wire that can be touched to the open side of the bat-

tery, Fig. 358. Disconnect the starter and the generator and open all the switches, then touch the bare end of the wire to the battery terminal on the open side as shown. Any reading, no matter how small, will indicate a short-circuit (two-wire system) in the wiring between the battery and junction box or between the latter and the starter, or generator. If the ammeter reading shows a heavy current, there is a severe short-circuit.

Localizing a Short-Circuit. The short-circuit may be localized in the same manner as described for the voltmeter test, i.e., connect the starter and test; disconnect the starter, connect the generator and test. A reading on the generator test may be due to the contacts of the cut-out sticking together. If the cut-out contacts are open and the ammeter registers, there is a short-circuit in the generator windings.

Disconnect the generator again, remove all the lamps from the sockets, and turn on the lighting-circuit switches one at a time, touching the wire to the battery terminal after closing each switch. A reading with any particular switch on indicates a short-circuit in the wiring of the lamps controlled by that switch. Only one switch should be closed at a time, all others then being open. This test should be made also with the ignition switch on but with the engine idle. The ammeter then should register the ignition current, which should not exceed 4 to 5 amperes. If greater than this, the ignition circuit should be examined.

Cautions. Do not attempt to test the starter circuit with the ammeter as it will damage the instrument. To test the starter circuit, reconnect as for operating, removing the ammeter. Close the starting switch; a short-circuit in the wiring will result either in failure to operate or in slow turning over of the engine. See that the switch parts are clean and that they make good contact. If the short-circuit is in the winding of the starting motor, there will be an odor of burning insulation or smoke.

The battery must be fully charged for making any of these tests. While the effect either of a ground or of a short-circuit will be substantially the same, its location and the remedy will be more easily determined by ascertaining whether it is the one or the other. Instructions for making these tests have already been discussed in the Gray & Davis section.

WESTINGHOUSE SYSTEM

Twelve-Volt; Single-Unit; Single-Wire

Dynamotor. The single unit of the 12-volt system, or the "motor-and-generator" as the manufacturers term it, is a bipolar machine, both the generator and starting-motor windings of which are connected to the same commutator. Installation is usually by means of a silent chain, as on the Hupp (1915 and earlier). The characteristics of this type of machine are such that when running at a speed equivalent to 9 miles per hour or less, it acts as a motor, and when the speed increases, it automatically becomes a generator and begins to charge the battery.

Regulation. The third-brush method of regulation is employed, the amount of current supplied to the shunt fields by this brush

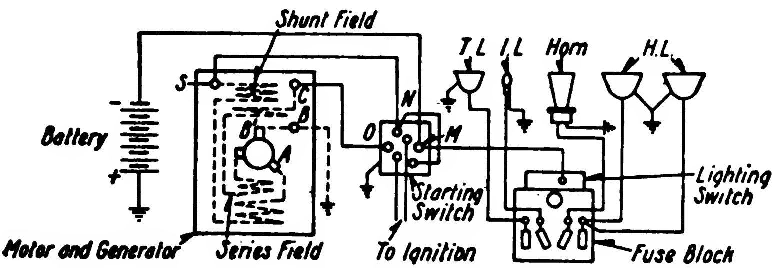


Fig. 359. Wiring Diagram for Westinghouse Single-Unit System on Hupmobile

decreasing as the magnetic field of the generator becomes distorted owing to increased speed.

Control. The switch employed with this type of combined unit is the regular single-throw single-pole switch used on lighting-plant switchboards. This switch controls both the ignition and the starting-motor circuits and, at starting, is thrown on and left closed as long as the car is running.

Wiring Diagram. The connections of the Hupp installation are shown in Fig. 359.

Instructions. *Battery Charging.* As the unit acts as a motor to drive the engine when the latter is running at a speed of less than the equivalent of 9 miles per hour on high gear, slow driving or permitting the engine to idle at a very low speed when the car is standing will discharge the battery. Where no fault in the wiring or connections exists and the battery will not stay charged (the

generator, of course, working properly), this practice may be the cause of the trouble. If the voltage drops to 10 or 11 volts, with the headlights on but with the engine stopped, it indicates that the battery is practically discharged. This voltage reading will be somewhat higher in summer than in winter. The remedy is to run with fewer lights at night or to run the engine for longer periods in the daytime, or at higher speeds. Running solely at night will not keep the battery sufficiently charged, as most of the generator output is consumed by the lamps. Should the battery become discharged to a point where it cannot operate the starting motor, disconnect the wires *C* and *S* at the dynamotor, taping their terminals to prevent contact with any part of the engine or chassis. Start the engine by hand and, when running at a speed of about 500 r.p.m., reconnect these wires, *being sure to connect wire S first*, when the battery will begin to charge.

Fire Prevention. Gasoline or kerosene is frequently employed to wash automobile engines. Before doing so, be sure that the starting switch is open, and disconnect the negative terminal of the battery, taking care that it does not come in contact with any metal parts of the car. To make certain of this, it is better to tape the metal terminal. Allow the gasoline to evaporate entirely before reconnecting the battery, as a flash or spark would be liable to ignite the vapor. This naturally applies to all cars, although only such as are equipped with the Westinghouse single-unit or the Dyneto single-unit have starting switches which remain closed all the time the engine is running.

Weak Current. If the dynamotor fails to operate when the starting switch is closed, open the switch and test with the portable voltmeter. If it indicates less than 11 volts, the battery is run down; if it indicates 12 volts or over, look for a loose connection or an open circuit (broken wire) either in the connection from the battery to the starting switch, from the switch to the dynamotor, from the latter to the ground, or from the battery to the ground, in the order named. Dim burning of the lamps when the engine is stopped also indicates a discharged battery. When this is the case, it is advisable to recharge at once from an outside source, if possible.

A quick method of determining whether there is a ground in the wiring is to disconnect the battery wire and, the engine being stopped

and all lights turned off, touch the disconnected wire to the terminal lightly. A spark, when this contact is made, will indicate a ground between the battery and the dynamotor or the switch. The testing lamp should then be used to locate the circuit in which the ground exists.

Failure to charge properly may be due also to imperfect contact at the brushes or to a break in the shunt-field circuit of the generator, as explained in previous instructions. If the shunt-field circuit is found open, the trouble doubtless has been caused either by a ground between the battery and the generator or by running the generator when it was disconnected.

To remove the brushes, lift the spring that holds the brush in the guide and take out the screw holding the brush shunt, when the brush

Fig. 360. Westinghouse Bipolar Generator for Six-Volt Double-Unit Single-Wire System
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

can be slipped out. Care should be taken to replace brushes in the same position, and if they do not bear evenly over their entire surface on the commutator, they should be sanded-in as described in the Delco instructions. The latter suggestion also applies to new brushes.

Six-Volt; Double-Unit; Single-Wire

Generators. Four types of generators are made, as illustrated in Fig. 116, Part III; in Fig. 157, Part IV; and in Fig. 360, shown herewith, the fourth being similar to the unit shown on this page except for the method of regulation employed, which is of the third-brush type.

Regulation. The reverse series-field winding, or bucking-coil, method is used in the first two types of generator, while a voltage regulator combined with the battery cut-out is employed on the

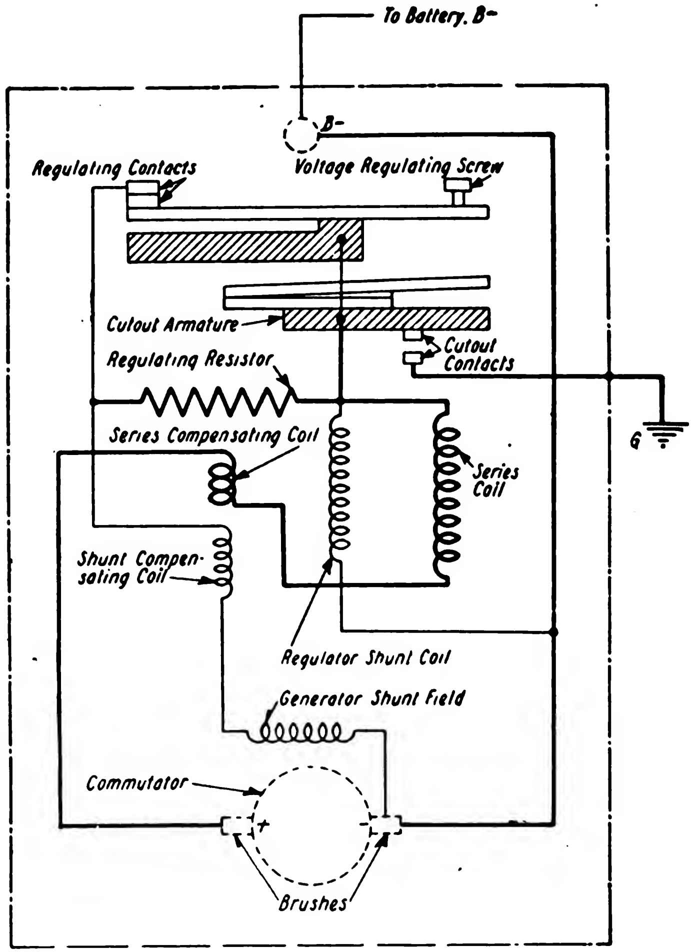


Fig. 361. Wiring Diagram for Westinghouse Generator with Self-Contained Regulator

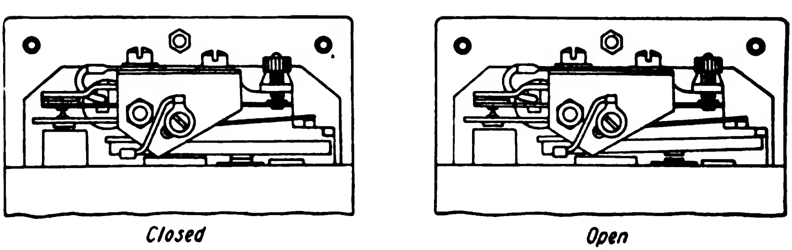


Fig. 362. Closed and Open Position of Westinghouse Cut-Out Switch

Fig. 363. Wiring Diagram for Westinghouse System with External Regulator

third, and the third-brush method on the fourth. This regulator is either self-contained, i.e., built in the generator, or is mounted independently. The connections of the built-in regulator are shown in Fig. 361. The open and closed positions of the contacts of the external cut-out are shown in Fig. 362.

Wiring Diagram. Fig. 363 shows the connections of the separately mounted regulator together with the charging and lighting circuits.

Fig. 364. Westinghouse Cut-Out Switch of Generator with Third-Brush Regulation

Battery Cut-Out. The type of automatic cut-out used with the type of generator employing the third-brush method of regulation is illustrated in Fig. 364. This may or may not be combined with a starting switch mounted on the engine side of the dash or some similar location. Fig. 365 is a wiring diagram showing the connections of the separately mounted cut-out with the third-brush generator. The cutting-in speed varies from five to ten miles per hour on high gear, varying with the gear ratio and wheel diameter of the car. This speed may be determined by running the car slowly and speeding up very gradually, meanwhile observing the increase in speed on the speedometer. The point at which the contacts close

will be indicated by a slight quick movement of the ammeter needle. The cutting-out speed is slightly below this to prevent constant

Fig. 365. Diagram of Connections for Complete Westinghouse System with Separately Mounted Regulator

vibration of the cut-out armature when the car is being driven close to the cutting-in speed.

Starting Motors. *Variations.* Several types are built to meet varying requirements; i.e., with self-contained reduction gearing, with single-reduction automatic screw pinion shift (Bendix drive), and with automatic electromagnetic pinion shift. The first two will be familiar from the descriptions already given of other makes. The third is similar in principle to the Bosch-Rushmore, but an independent magnet is employed instead of utilizing the armature of the motor itself for this purpose.

Magnetic Engaging Type. This type, as well as the other types of starting motors mentioned, may be operated either by a foot controlled switch or by a magnetically controlled switch put in action by a push button. The wiring diagrams, Fig. 366, show the circuits of both installations and also make clear the operation of the auto-

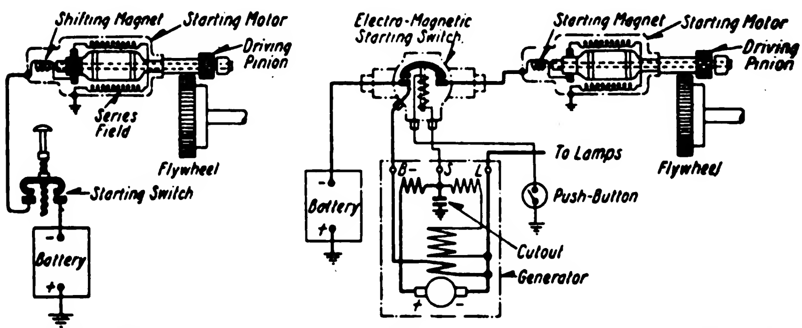


Fig. 366. Wiring Diagrams of Motor Connections for Automatic Electromagnetic Pinion Shift

matic engagement. The armature is mounted on a hollow shaft; and on the end of this shaft is carried a splined pinion designed to engage the flywheel gear. This pinion is caused to slide along the shaft by a shifting rod which is attached to the pinion and passes through the hollow shaft. The other end of this shifting rod acts as the core of the shifting magnet and will be recognized as the plunger of a solenoid. When the motor is idle, a spring holds the pinion at the right-hand end of the shaft and clear of the flywheel gear.

As shown diagrammatically in Fig. 366, when the starting switch is closed, the circuit is completed from the negative terminal of the battery, through the switch, the shifting solenoid, the armature, and the series field of the motor to the frame of the car on which the positive side of the battery is grounded. The large amount of current necessary for starting energizes the shifting solenoid suffi-

ciently to overcome the force of the spring so that it draws the shifting rod to the right through the hollow shaft, meshing the pinion with the flywheel gear. When the engine speeds up to the no-load speed of the starting motor, the current in the latter falls off so that the pull of the solenoid is less than that of the spring, and the pinion is automatically disengaged, though the motor will continue to revolve until the starting switch is opened.

Electromagnetic Switch. In principle, the electromagnetic switch is the same as that of the automatic engaging device for the pinion. The movable double-pole contact, instead of being attached to a rod for foot operation, is mounted on the plunger of a solenoid and normally is held open by a spring. This solenoid requires but a small amount of current for its operation and is connected on an independent circuit with the battery. It is controlled by a push button, and when the circuit is closed by means of the latter, the plunger of the solenoid is drawn into the coil against the pull of the spring, thus bringing the contacts together and holding them there as long as the solenoid is energized.

Instructions. *Regulator.* When the generator of the voltage-regulator type fails to charge the battery properly, all parts of the circuits and connections having been examined to determine that they are in proper condition, the regulator may be tested for faults. With the aid of the portable voltmeter, note at what voltage the contacts of the cut-out close or *cut in,* and at what voltage they *cut out* or open. See that the contact points are clean and square so that they make good contact over their entire surfaces when pressed together with the hand. Insufficient charging may be due to the voltage regulator keeping the voltage of the generator below the proper point for this purpose. A voltage adjusting screw is provided to compensate for this. With the voltmeter in circuit and the engine running, turn the screw very slowly and note the effect on the reading. For proper charging the latter should be approximately 7½ to 8 volts, and the screw should be adjusted very gradually to bring the voltmeter reading to this value. This screw is properly set at the factory and is unlikely to need adjustment; so all other possible causes should be investigated before changing it. The instructions for the 12-volt system also apply here, except that for voltage tests the system operates on 6 volts.

FRONT VIEW OF HEINZE-SPRINGFIELD FORD STARTER MOUNTED ON CAR

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART VII

ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

INSTALLING SPECIAL SYSTEMS FOR FORD CARS

General Instructions. Most of the leading manufacturers who make the starting and lighting equipment for larger cars also manufacture a special type designed for the Ford. Almost without exception these special Ford systems are simple and compact, and everything necessary to install them on the machine is provided by the maker of the apparatus. Where the system is to be installed, either by the owner of the machine or by the local garage man whose electrical experience is limited, the choice of the most suitable system often is decided by the ease with which it may be installed. In practically every case this necessitates the removal of the radiator, radiator brace rod, hose connections, fan, fan pulleys and belt, cylinder head, and in some cases the timing-gear housing. In the majority of instances the ground connection of the headlights—which is soldered to the back of the radiator on 1915 and subsequent models provided with electric headlights supplied by the Ford magneto—must be discarded altogether, as the lights are to be supplied by the storage battery. In cases where it is necessary to remove the timer (this must be done when the timing-gear housing has to be removed), both the timer and the carburetor should be adjusted for efficient running before starting to dismantle the engine, and if the latter is turned over while the timer is off, the ignition timing must be readjusted when the timer is put back. As the removal of all the parts mentioned is a simple matter fully covered in the Ford instruction books and familiar to practically every garage man in the country, they are not repeated here.

In starting to install any system, one of the first precautions to take before attempting to dismount any of the parts of the engine is to check over the list of parts sent with the outfit with those actually received. The reason for this is that it at times an essential part has been omitted, and this is not discovered until a large part of the labor of dismounting the engine has been carried out; the work must be done all over again or the engine kept dismounted until the missing part arrives.

GENEMOTOR

Chain-Driven Type

Mounting Starter. Drain the radiator and remove it with the water-pipe and elbow connections from the engine; remove the starting-crank claw and take out the starting crank; take the fan-belt pulley off the engine shaft, the fan and the supporting arm from the cylinder casting, the primer rod from the carburetor and timer-advance rod; take out the second and third right-hand crankcase bolts *A*, Fig. 367. Clean the engine thoroughly to insure proper seating of the bracket and with a file remove any high spots, or fins, on the casting that would interfere. Mount the unit on the engine, first inserting the base bolts and then the water-flange bolts with elbows. Place gaskets each side of the bracket. Use the plain washers between the engine case and the foot of bracket *D* to insure proper support and alignment with the water-pipe connections *E* and *F*. Attach the driving sprocket *G* to the crankshaft, using the new pin *H* supplied. It may be necessary to bend the crankcase nose slightly at *I* to provide clearance for the chain on the right side and to chip off part of the rivet heads under the sprocket. There should be at least ½-inch clearance at all points around the sprocket after the chain is in place.

Replace the starting crank and claw and turn the engine over slowly by hand to feed the chain on to the sprocket. Connect the ends of the chain together, noting the arrows on the side of the chain, which show the direction in which it must rotate. Before connecting the chain, the Genemotor fan pulley with internal spring should be removed as a unit to prevent the possibility of changing the spring adjustment. Care should be taken that the slot in the spring support into which the forks of the pinion assemble clears the key. These can

be brought into line by holding the pinion and turning the fan pulley in a counter-clockwise direction (to the left). Loosen the clamping

Fig. 367. Working Drawing for Installing Chain-Driven Genemotor
Courtesy of General Electric Company, Schenectady, New York

strap and tilt the whole unit slightly to receive the chain. Apply a straightedge, as shown in Fig. 368, and align the sprocket accurately,

making sure that the Genemotor shaft is parallel with the crankshaft and that the pinion with bushing is pressed against the ball bearing. Allow a slight amount of slack in the chain when adjusting by means of the two set screws *K*, Fig. 367, which raise the unit in its cradle. When such adjustment is made, be sure that the starting switch is in an upright position on top of the motor and tighten the clamping strap. Grease the chain thoroughly and attach the chain guard *L*. Replace the pulley with spring locking with pinion, as when received. Assemble the clamp pulley supplied for driving the fan on to the regular fan pulley, reducing the flanges of the latter by filing, if necessary. Replace the fan and the bracket *O* on the engine. If the fan blades should not clear the Genemotor pulley, twist them slightly with a wrench and bend out the tips of the fan blades. Put back the old fan belt, but do not adjust it too tightly. Replace the timer rod, bending it as necessary to make sure that it clears the chain properly. Turn the engine over by hand to make sure that the chain is free and properly adjusted; it is important that the chain should not touch the nose piece or forward end of the crankcase or the side rivet heads. Before replacing the radiator and hose connections, it is advisable to run the engine a few minutes to note alignment, clearance, and operation.

Fig. 368. Method of Checking Chain Alignment with Straightedge

The dashboard is to be drilled for the lighting switch *Q* on the right-hand side, as viewed from the seat, directly under the carburetor adjustment and for the starting-switch rod *R* on the left-hand side close to the coil box. On the sedan, coupelet, and 1915 models, the

lighting switch may be placed on the upper left-hand corner of the heel board under the driver's seat, or it can be mounted on the dash close to the speedometer. Mount the primer lever and the special washer *S* under the second manifold stud nut, passing the original rod through the dashboard.

Wiring. All of the leads are marked for identification, and the wiring diagram will be readily understood from Fig. 369. The battery box should be mounted on the right-hand running board so as not to interfere with entrance to the car, and so that the hole in the bottom of the battery box overhangs the running-board shield, through which a new hole must be cut. The battery leads, protected by the circular loom supplied for the purpose, should be run through this hole. The motor cables supplied with this outfit are to be run diagonally across the transmission case of the engine from the unit to the battery. Where they cross the transmission case, these leads are supported by a steel clip furnished for the purpose, the clip being secured under the right-hand screw holding the transmission cover in place (next to the dash). In installing the leads, the screw in question should be removed, the clip placed over the wires, and all secured by returning the screw through the clamp to its original position. The two hold-down straps are to fasten the battery box securely to the running board, the clamps fastening to handles of the battery case and passing through the running board. Where wiring passes through holes cut

Fig. 369. Wiring Diagram of Genemotor Ford Installation

in sheet-iron parts, it should be protected by extra taping to avoid danger to the insulation from chafing. Make certain that all connections are clean, are properly made as shown on the wiring diagram, and are clamped tightly.

On the 1915 and subsequent models, on which the headlights are electric and are supplied with current from the magneto, it will be necessary to discard the wiring and switch connections and to do away with the ground connection soldered to the back of the radiator, as

Fig. 370. Ford Frame Stripped for Mounting Shaft-Driven Genemotor

the new system is of the two-wire type throughout, and all the lamps are fed with current from the storage battery through a lighting switch on the dash.

Operation. The Genemotor is a single-unit type, the same machine performing the functions of both generator and starting motor. The starting switch and the reverse current relay, or automatic cut-out, are in a small housing mounted directly on the machine. Starting is effected by pushing the switch rod forward. The switch will open automatically when the rod is released. During the first hundred miles, it will be necessary to watch the chain carefully and

take up the slack as the links seat themselves in the sprockets. Whenever it shows excessive slack, the chain should be tightened so that it will not deflect more than $\frac{5}{8}$ inch from a straight line by the pressure of the fingers. It is very essential to the life of the chain that it be not allowed to run too slack. The occurrence of any undue amount of noise in operation is a sign that the chain is too slack. The chain must always be kept sufficiently tight to prevent striking the guard or the nose of the crankcase and it is very essential that it be greased every two weeks.

Shaft-Driven Type

Preliminary Adjustments. Before dismantling the engine, be sure that it is in good running condition and that the carburetor is properly adjusted. Remove the radiator with the water-pipe and elbow connections, starting crank and claw or dog clutch, fan bracket complete with fan and belt, fan-drive pulley on crankshaft, timer or commutator complete, timing-gear cover (leave paper gasket and engine bolts *A* and rear sill bolt *B*, Fig. 370). Cut out the dashboard as shown. Remove the felt packing rings used around the crankshaft and camshaft from the old timing-gear cover, or housing plate, and place them in the new timing-gear cover supplied (sometimes referred to as the "cylinder front cover"). Reassemble, putting the new timing-gear cover in place, using bolts *E*, *F*, *G*, and *H* in the holes indicated, Fig. 371, and using lock washers. Leave the bolts slightly loose. Throw the hand-brake lever into middle position and push the crankshaft back as far as it will go. Assemble the split hub *J* on the crankshaft, inserting the hub pin through a set of holes in the hub which give not less than $\frac{1}{32}$- and not over $\frac{3}{32}$-inch clearance between the back of the hub flange and the timing-gear housing.

Fig. 371. Timing-Gear Cover Assembly

Drive the hub pin *K*, Fig. 372, into the crankshaft, being careful that the ends are an equal distance below the surface of the threaded

portion of the hub. Chisel off parts of the rivet heads *XX*, Fig. 373, in the pan of the engine and assemble gear ring *L* and place on the hub. In some cases it may be found necessary to bend out the side of the nose pan slightly by means of a wrench, as shown, to obtain the necessary clearance for the gear ring, which must not be less than $\frac{1}{64}$ inch at any point. The recess in back of the gear ring will facilitate its insertion past the front of the crankshaft. Fasten the gear ring to the hub flange with the three screws and lock washers provided.

Fig. 372. Fitting Split Hub on Crankshaft

Throw the hand brake in the extreme forward position to lock the engine and screw the hub nut *M*, Fig. 372, on the hub, tightening it with a $\frac{3}{8}$-inch steel rod inserted in the holes provided. Replace the

Fig. 373. Mounting Gear Ring and Adjusting Nose Pan in Genemotor Ford Installation

starting handle minus its original starting ratchet, or dog clutch, using in its place the ratchet pin supplied, and retain it in place with the cotter pins *N* supplied, Fig. 372. Remove the leather coupling *P*,

Fig. 374, complete from the end of the pinion shaft. Unscrew the bearing-housing cap Q, Fig. 375, from the timing-gear cover and lay

Fig. 374. End and Side Elevations of Motor and Driving Shaft
Courtesy of General Electric Company, Schenectady, New York

the bearing lining with pinion shaft in place. *The coupling is keyed to the armature shaft and the drive shaft. Always remove the coupling complete by driving it off either shaft. Do not separate the leather from the*

flanges. Be sure that the lining screw R, Fig. 375, in bearing the cap enters the hole in the bearing lining before replacing the cap, and that the shaft does not strike the base of the engine casting, which would spring the shaft. If necessary, file away the corner of the engine base to clear the shaft by at least $\frac{1}{32}$ inch.

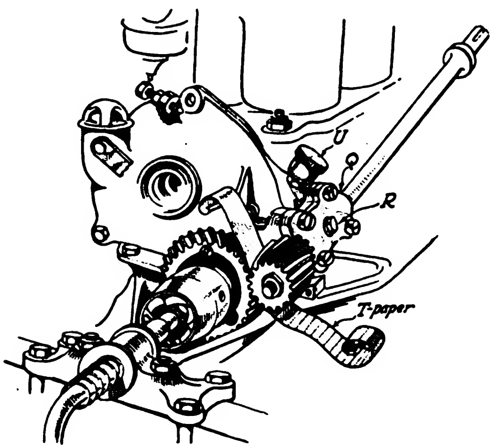


Fig. 375. Adjusting Driving Pinion

Adjustment of Gears. The steel gear must at all times run on the *fabroil* teeth of the pinion and not on its steel shrouds. To accomplish this, rearrange the steel pacers *S*, Fig. 374, on the pinion shaft, placing them more or less forward or back of the lining, as may be necessary. *In no case should any washers be left out.* Throw the hand-brake lever into middle position and turn the engine over with the crank, feeding in between the gears a strip of the paper *T*, Fig. 375, supplied for the purpose. Lightly tap the timing gear to the left as far as necessary to mesh the gears tightly. Tighten up the retaining bolts. Turn the engine over again to feed the paper out. The paper should be evenly marked but not cut. If the paper shows signs of cutting through at any point the gears are meshed too tightly. *Do not, under any circumstances, place any shim between the bearing lining and its supporting housing.*

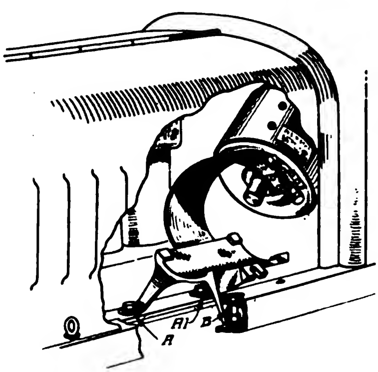


Fig. 376. Motor Cradle Assembly

Mounting the Genemotor. Assemble the motor cradle in place, Fig. 376. Place a $\frac{1}{8}$-inch spacing washer under the leg nearest to the transmission cover and insert the special bolt *A1* with the lock washer from the underside of the car but leave it slightly loose.

Put in place the front leg bolt A and the new sill bolt B with lock washers but do not tighten up. Insert the Genemotor from the rear side of the dash through the hole previously cut for the purpose, sliding it on to its cradle, and clamp in place with the steel strap, leaving about $\frac{3}{8}$-inch space, Fig. 377, between the motor shaft and the pinion shaft. The flat space on the motor body should be parallel to the iron dash support.

Fig. 377. Checking up Alignment of Motor Shaft and Pinion Shaft

Motor Alignment. Raise the front leg and the sill leg of the cradle by a suitable thickness of spacing washers supplied until the ends of the shaft are in line, utilizing the clearance in the bolt holes to obtain the sidewise adjustment. *The ends of the shafts must be lined up accurately to within $\frac{1}{64}$ inch, or the bearing will overheat and be destroyed.* Check the line-up as shown in Fig. 377. When the

Fig. 378. Priming Rod and Lever Adjustment

adjustment is satisfactory, tighten all the bolts, setting up the lower nut on the sill bolt first and re-check the line-up; if necessary,

readjust. Remove the bearing cap and the pinion shaft. Assemble the leather coupling on the pinion shaft, then assemble the other end of the coupling on the motor shaft; both should be a light drive

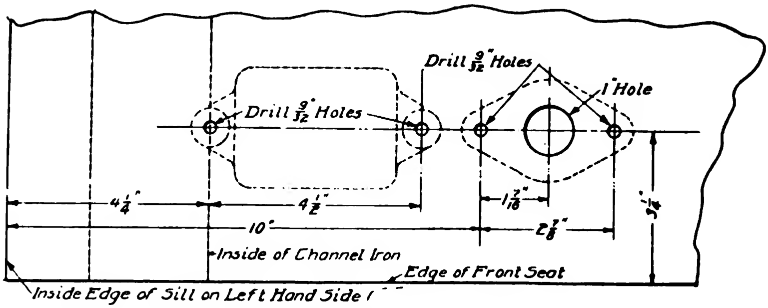


Fig. 379. Layout on Under Side of Heel Board for Starting Switch and Cutout

fit. Fill the recesses in the bearing lining and bearing with a good grade of non-acid grease. Replace the lining and shaft in the housing and secure the cap in place. Fill and fully compress the grease cup *U* twice to assure that the grooves and pockets are filled, Fig. 373. Also thoroughly grease the gears and assemble the gear guard with its two screws and lock washers. "Gredag No. 32-inch" (semi-liquid graphite grease) or its equivalent in powdered graphite lubricant is recommended for this purpose.

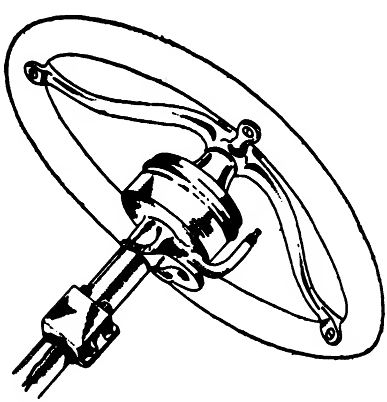


Fig. 380. Lighting Switch Mounted on Steering Post

Replace the Ford commutator, or timer, setting it with the steel brush upward when the exhaust valve of cylinder No. 1 is closed, as mentioned in Ford ignition instructions. Fit the two-piece fan pulley around the neck of the Ford fan pulley and secure it with screws and lock washers provided. Reassemble the fan and bracket complete, using a new 1-inch belt, which is driven from the pulley on the gear hub nut *M*, Fig. 372. Replace the radiator and the water connections to the engine, using a special bolt for the elbow connection nearest the genemotor. Replace the spark-advance rod,

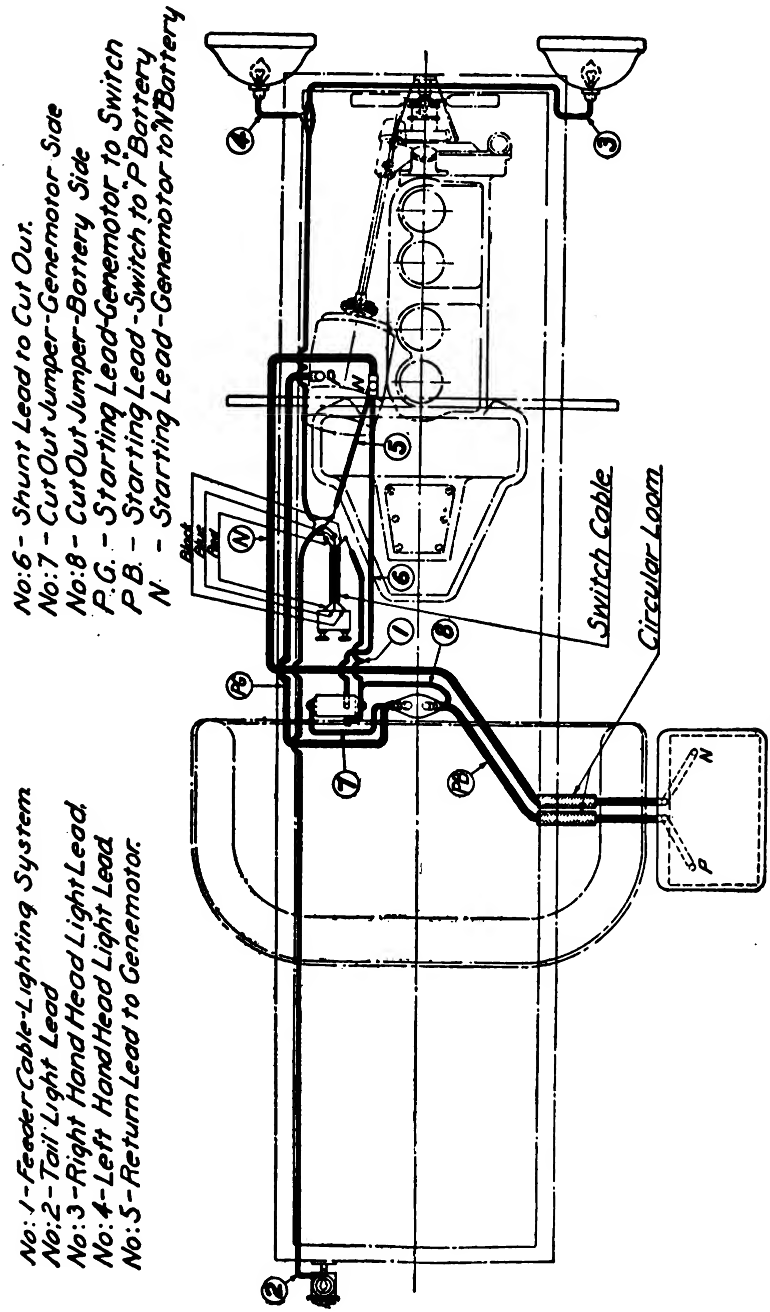


Fig. 381. Wiring Diagram for Head and Tail Lights
Courtesy of General Electric Company, Schenectady, New York

bending it to pass over instead of under the water connection, before fastening it to the timer. The throttle rod must be turned upside down and assembled with cotter pins toward the dash to clear the coupling. Attach the primer rod and lever, as shown in Fig. 378, using part of the Ford primer rod originally coming through the radiator. Mount the starting switch and cut-out on the underside of the heel board, Fig. 379. The rubber floor mat must be cut to fit the foot plunger.

Mount the lighting switch on the steering column, Fig. 380, clamping the cable attached to it between the recess in the switch box

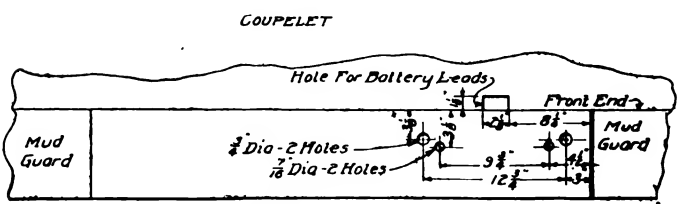


Fig. 382. Layout of Right Running Board for Mounting Battery Box on All Ford Models

and column, and wire up the head and tail lights, Fig. 381, with leads supplied. Each lead is tagged to correspond with the wiring diagram. Drill holes in the right-hand running board for the battery box, Fig. 382, including the slot in the side panel where the main cables will pass through, and bolt the battery box on to the running board. Connect the Genemotor to the switch and cut-out, Fig. 381, placing on each battery cable a piece of the circular loom (supplied) at the point where the cables pass through the slot cut in the side panel, securing the circular loom in place by taping each end of the loom

to the cable. Each cable is tagged to correspond with the wiring diagram. Place the battery in the battery box, allowing it to rest on the wooden supports (supplied) and clamp through the box to the running board with battery clamps. Connect the negative lead to the negative terminal of the battery, then touch the positive lead to the positive terminal. If no spark occurs when the positive terminal is touched, connect up permanently; should a spark be noticed, it indicates a short-circuit or a leak in the system, and the wiring will have to be gone over carefully to correct it before connecting up permanently, otherwise the battery will discharge itself. Turn the engine over slowly by hand to see that everything is clear. The starter and the lights are now ready for use.

Operating Instructions. *Whenever it is necessary to remove the battery for any reason, never operate the generator unless its terminals are first connected together with a copper wire or cable, otherwise the generator will overheat and injure its windings. The lights cannot be used with the battery off the car. Never operate the generator with the small regulating brush removed or with its contact surface reduced, as normal charging current will not be generated, and the battery will not charge properly.*

In extremely cold weather, it is advisable to "break away" the engine by hand, giving the crank a few turns to loosen the lubricating oil on the pistons and bearings, thus preventing undue drain on the battery. The starter is designed to spin the engine at a speed sufficient to insure easy starting on the Ford magneto. If the engine does not fire promptly, pull out the priming rod at the forward end of the radiator and turn the engine over two or three times by hand before closing the starter switch again. Should the engine still fail to start, examine the timer, squirting a liberal supply of one-fourth kerosene and three-fourths lubrication oil into it; see that there is plenty of gasoline in the tank and that it is reaching the carburetor. Turn the carburetor, or gasoline-supply adjustment, on the dash up (to the left) to insure a liberal supply of gasoline in cold weather. When an easy starting point of this adjustment has been found, it should be marked by filing a nick or arrow on the small brass wheel; turning the latter with the arrow upright will then insure easy starting in cold weather. After the engine has run a short time and become warmed up, the wheel can be turned down 15 to 20

degrees (to the right), and several more miles per gallon will be secured. When the engine does not get under way promptly, do not exhaust the battery unnecessarily by continuing to run the starter. In any case where the engine fails to start the first time and examination shows everything to be in good condition, operate the starter intermittently a few seconds at a time but not continuously.

Failure to Start. When the starter fails to turn the engine over, try cranking by hand to make sure that the crankshaft is free to revolve before attempting to make any adjustments. If it turns freely by hand but the starter cannot move it, test the condition of the battery charge with the hydrometer. In winter, particularly, cars are often run for days at a time on very short runs with frequent stops and starts, and under such conditions the battery is likely to become exhausted, as the average charge is less than the requirements imposed upon it by the great number of starts made. In such cases, it may be necessary to give the battery a special charge from an outside source or by running the engine with the car standing.

Ammeter. A recording instrument is not regularly supplied as a part of the system, since the generator is fitted with an inherent type of regulation having no moving or vibrating parts, so that as long as the system is kept in good condition, charging is assured. Where the owner considers the addition of an ammeter desirable as a means of checking the operation of the system, the instrument can readily be added by removing the jumper wire on the starting switch and connecting the ammeter leads across these two posts. The lamps recommended for use with the system are 12- and 14-volt 15-c.p. Mazda or 24-c.p. nitrogen (not desirable, as it causes too much glare), and 12- and 14-volt 4-c.p. Mazda for the tail light. For care of battery, see sections on Battery Charging and Maintenance.

GRAY & DAVIS

Installation. *Preparing Engine.* Remove the radiator, disconnecting the ground wire from it; disconnect the wires from the head lamps and remove the head lamps and supports. Take off the bracket and fan, Fig. 383, and turn the engine by hand until the pin *2* in the fan pulley is straight up and down; remove the pin from the jaw clutch and remove the starting-crank *4*, belt *5*, and the cotter pin, *3;* take the pin from the fan pulley and remove the pulley *6*. Remove

the second, fourth, and fifth bolts from the crankcase flange *7*, the left and front bolt from the side-water connections *8* and *9*, as well as the second cylinder-head bolt *10*.

NOTE—The numerals refer to the parts to be removed or replaced, as well as the sequence in which the operations are to be carried out, as shown on the sketches. Each illustration, however, has its own series of the same numbers, which should not be confused with those on other views.

Lay the chain *1* in the rear of the engine support around the crank-shaft, Fig. 384, and then place the original starting-crank jaw

Fig. 383. Preparing Engine for Mounting Starting Unit
Courtesy of Gray & Davis, Boston, Massachusetts

clutch *2* inside of the crankshaft sprocket. Place the crankshaft sprocket *3* on the crankshaft and put the new belt *4* around the pulley on the crankshaft. Secure the sprocket with the new pin *5* (supplied) and then connect the starting crank in its original position. Secure the jaw clutch to the starting crank with pin *7*.

Mounting Starter-Generator. In Fig. 385 is shown the starter-generator unit, for which note the following instructions: See that

Fig. 384. Putting Driving Chain on Crankshaft Sprocket in Gray & Davis Ford Installation

Fig. 385. Details of Gray & Davis Generator Unit for Ford Starter

the motor terminal *1* is free from contact with any other metal; also that the dynamo terminal *2* and insulation are not injured. Test the shaft and gears *3* to see that they turn freely, and then fill the oil cups *4* with oil.

Release the top adjusting screw *5*, also two lower clamping lock nuts *6* (front), as well as the two upper clamping lock nuts *7* (rear) and the single middle clamping lock nut *8* (front). The units must be in the lowest position possible on the bracket before placing it on the car. In Fig. 386 is shown the starter-generator unit in place on the engine with the bolts and nuts all tightened. This is carried out as follows:

Fig. 386. Starter Unit Mounted on the Engine
Courtesy of Gray & Davis, Boston, Massachusetts

Place three $\frac{3}{8}$-inch spacers over the first, second, and third holes in the crankcase flange *1*, and then place the unit on car *2*; pass three $\frac{3}{8}$- by $2\frac{1}{8}$-inch bolts through the lower bracket, but do not attach nuts *3*. Tip the starter unit forward and pass the chain over the dynamo sprocket *4*; attach the bracket by meams of cylinder-head bolt, but do not fasten.

Place a $\frac{13}{32}$-inch spacer between the bracket and top water connection *7* and attach the bracket with $\frac{7}{16}$- by $2\frac{5}{8}$-inch bolts, but do not fasten securely; then place $\frac{1}{32}$-inch spacers *7A* under the bracket

so that the chain will be tight when the units are in the lowest possible position. Use washers *8* as shims between the bracket and the cylinder-head link. Secure the three lower bracket bolts *9* with lock washers and nuts, also secure the water-connection bolts *6* and *7* and the cylinder-head bolt *5*. Adjust the bracket stay bolt *10*, adjust the chain *11* to moderate the tension and lock adjustment, securely tighten five clamping bracket nuts, and then crank the engine slowly by hand to see that everything turns smoothly. If, through some irregularity in the engine casting the bracket should not seat properly, it may be necessary to file the bracket holes to meet this condition. Be sure that the sprockets are in true alignment, or the

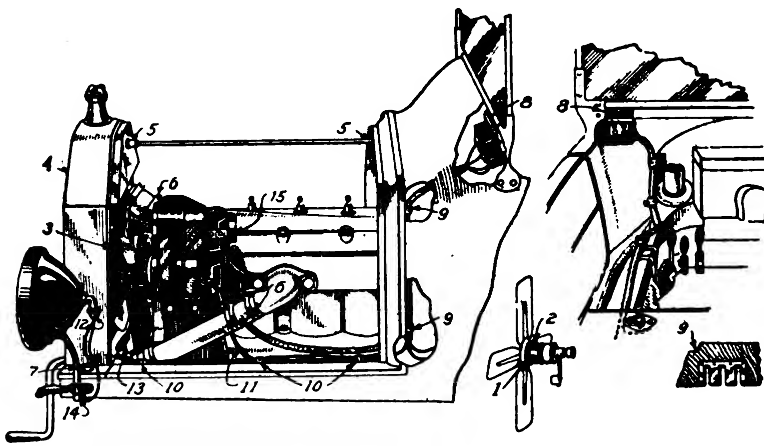


Fig. 387. Installing Gray & Davis Wiring and Lighting Switch on Ford Car

uneven strain may cause injury. If necessary, elongate the holes in the bracket or shim bracket as needed to insure perfect alignment of chain.

When adjusting the bracket stay bolt *10*, make sure that it rests against the engine casting without strain and secure it with nuts on each side of the bracket. Bend the ignition timing to clear the chain, if necessary, but after bending, the distance between the ends of the rod in a straight line must be equal to its original length. Adjust the chain to moderate tension and secure both the adjustment lock nuts at the top. If all five nuts holding the adjustable bracket are not released before adjusting, uneven strain may cause injury. Securely

tighten the sliding-bracket nuts *12*—two at the bottom front side, two at the top rear, and one at the front end. Test by turning the engine over by hand slowly.

Remounting Engine Parts. Fit split pulley *1* to the hub of the fan, Fig. 387, and attach split pulley *2* with four screws; slip a new belt over the fan pulley, attach the fan, and adjust. Place the radiator *4* on its support and screw the radiator rod into the radiator and secure with check nut *3;* secure the hose clamps at the top and side water connection *6;* place the radiator nuts and secure with cotter pins. Attach the lighting switch at the cowl (left) with $\frac{3}{16}$-inch screws and attach three lighting-cable clips on the rear of the dash, using $\frac{1}{2}$-inch wood screws; cut the corner from the toe board for clearance. Attach three wire clips *10* to the left side of the frame and attach green wire *11* to the dynamo terminal. Then connect the short black and red wire to the left head lamp. Pass a long black and red wire through the radiator tube to the right head lamp, then connect the short wire from each head lamp to the metal of the car frame *14*. Attach the starting cable *15*, which has a copper terminal at each end, to the starting-motor terminal. Refill the radiator and watch carefully for leaks in the circulation system.

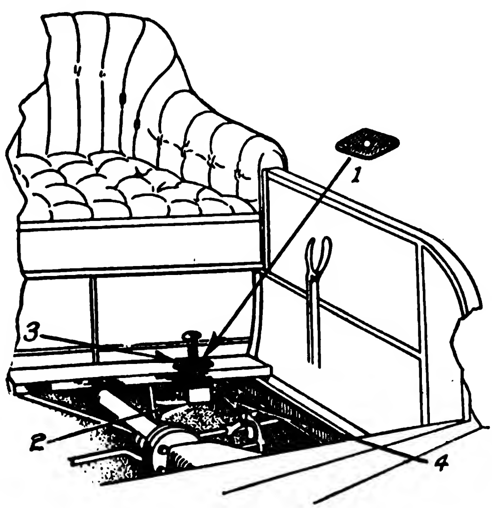


Fig. 3 8. Installation of Starting Switch
Courtesy of Gray & Davis, Boston, Massachusetts

Starting Switch. The location of the starting switch and the method of installing it are shown in Fig. 388. Take the plate *1* off the starting switch and use it to mark the holes in the floor strip two inches in front of heel board and nine inches from the sill, as shown in the illustration. Make three holes for the starting switch in the rear floor strip *2* and attach the switch with bolt *3* at the side nearest the center of the car; then attach the other switch bolt *4*, support

the cable clip holding the two wires, and secure the spring and the knob with a pin.

Priming Device. Connect the priming device *1*, Fig. 389. Drill a $\frac{7}{32}$-inch hole in the dash two inches to the right of the coil box and six inches above the toe board and pass the upper rod through. Connect the lever arm *2* vertically to the foremost exhaust manifold bolt with stationary member in horizontal position; then connect the lower rod *3* to the carburetor priming lever. Work it back and forth several times to make sure that it returns to normal position when released.

Battery. Place the battery box on the right-hand running board. Fig. 390, to permit easy opening of doors and access to battery box;

Fig. 389. Replacement of Carburetor Timing Rod on Dash
Courtesy of Gray & Davis, Boston, Massachusetts

then mark four holes with the center punch. Drill four holes $\frac{11}{32}$ inch in diameter in the running board *2*, using a jack or prop to support the running board while drilling. Replace the battery box on the running board in order to mark the holes in mud guard for insulating cable bushings *3*, then make two holes $1\frac{3}{8}$ inches in diameter. Insert insulating-cable bushing *4* in left hole and secure with round wooden nut; do the same with the right-hand bushing *5*. Secure wood nuts *6* with a wire twisted around the thread. A coat of heavy paint will also hold the nut in place and preserve the insulator. Place the two flat wood cleats *7* with holes at each end between the battery box and the running board; then pass four bolts *8*, $\frac{3}{8}$ inch by $1\frac{1}{2}$ inches, through

the battery box, cleats, and running board, and secure them with four nuts and lock washers. Place two special-shaped wood cleats *9* inside the battery box, one at each end for the battery to rest upon, so that holes in the cleats will fit over the bolt heads. Raise springs *10* and hang on the side of the battery box, placing the battery in the box and inserting two ½-inch wood strips, one each side between the battery and the battery box. Attach two springs *11* at opposite ends

Fig. 390. Installing Gray & Davis Battery and Wiring

to hold the battery down securely. Inspect the battery and if the solution does not cover the plates at least ¼ inch, add pure water, filling the cells to ⅜ inch above the tops of the plates. Water for battery use should be free from iron or alkali.

Final Connections and Adjustments. Fig. 391 is a plan view of the chassis, showing the entire system in place. Figs. 392 and 393 show the wiring in plan and in perspective. Drill and attach to the woodwork on the underside of the body *1* three wire clips holding the

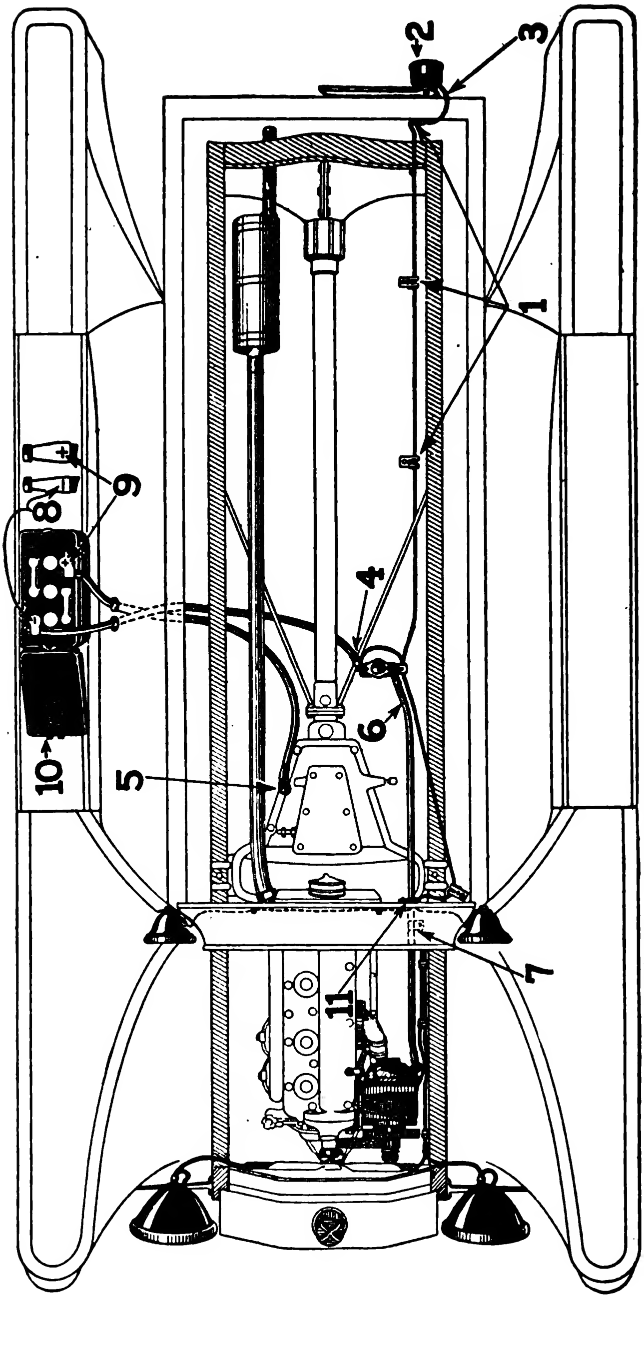


Fig. 391. Plan View of Complete Wiring System for Gray & Davis Ford Installation
Courtesy of Gray & Davis, Boston, Massachusetts

tail-light wire; see that the wire does not make contact with any metal edges. Attach the electric light *2*. If the tail lamp has a one-point wire connector, the lamp body must be metallically connected with

Fig. 392. View of Complete Wiring System Simplified

the chassis frame. Be sure the connecting surfaces are clean, free from paint, and securely connected. Connect the tail-light wire *3* to the tail lamp. Tail lamps are usually made with a single wire connector, but, if the lamp has two wire connectors, another wire

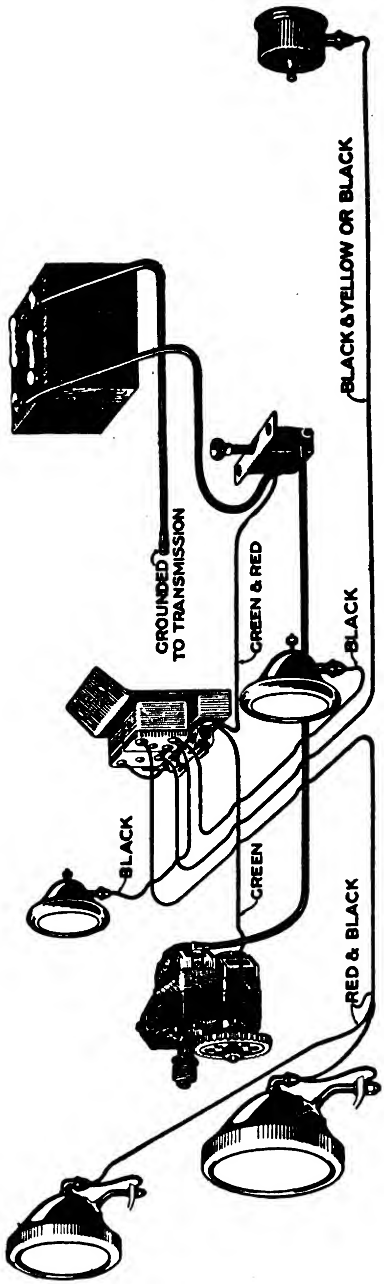


Fig. 393. Pictorial View of Wiring Diagram for Gray & Davis Ford Installation

should run from the second terminal of the connector to the metal framework of the car. Connect the short starting cable *4* (negative) and the green and red wire to the starting-switch terminal nearest the battery. Then pass the end of the battery cable through the foremost insulator in the mud guard. Attach the end of the starting cable *5*, leading through the rear hole in the mud guard, to the second bolt in the transmission case. Use a lock washer and a plain washer under the head of the bolt to insure permanent contact. Connect the long battery cable (positive) to the second transmission bolt and secure with a plain washer and a lock washer. Then pass the end of the cable through the rear insulator in the mud guard. Attach to the starting-switch terminal *6*, securely, the end of the cable which runs to the starter. Support the starter cable *7* by a clip to the inside curved edge of the dash. When connecting cables to the battery, be sure that the terminals are securely fastened—firm contact must be made. The battery terminals are made of lead and must be handled carefully. Battery-cable terminals

differ slightly in size and correspond to the holes in the battery terminal, the negative-cable terminal being the smaller. Pass the foremost cables *8* through the battery-box insulator and connect them firmly to the negative battery terminal. Do not connect the positive cable to the battery or insert the fuses until the installation has been made in accordance with the instructions and tests show that wires are not in contact with the frame of the car. Turn the lighting switch off and touch the positive terminal lightly to the battery terminal. If there is a spark, it indicates a short-circuit or a ground, caused by a wire coming in contact with the frame. Remedy the trouble before connecting up the battery. If there is no spark, permanent connection may be made. The lamp-test set may be used to determine whether there are any grounds or short-circuits, before connecting up the battery.

When all indications show that the installation has been made properly, connect the positive starting cable to the positive terminal *9* of the battery. Place and secure the cover *10* on the battery box. Place fuse *11* in fuse clip of lighting switch. Fig. 394 shows details of the different types of lamps.

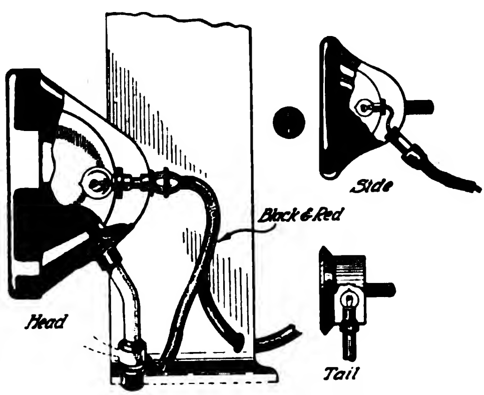


Fig. 394. Details of Gray & Davis Ford Lamps

Instructions. Oil the two generator bearings and the two motor bearings every 200 miles, keeping oil-well covers closed The chain must be kept well adjusted. When the unit is first installed or when a new chain has been fitted, the chain should be adjusted occasionally during the first 500 miles of travel until all stretch has been taken out of it. After this distance has been run, the chain stretch will be slight. Never allow the chain to run slack.

To adjust the chain, release five clamping nuts (2 nuts in the rear of the bracket at the top, 2 in front of the bracket at the bottom, and 1 at the right-hand side) a few turns to permit the bracket to slide. Then adjust the chain to moderate tension by turning the adjusting

screw at the top of the bracket and tighten the check nut and adjusting screw to lock the adjustment. Then retighten all five clamping nuts securely. Turn the engine by hand to determine whether the chain runs smoothly; the chain should not be too tight. After long service, when all chain adjustment has been taken up, the chain may be shortened by taking out a pair of links. The latest type of chain is supplied with a removable pair of links, retained in position by two removable pins. These pins are a trifle longer than the regular riveted pins.

Where the chain has been shortened, it is sometimes necessary to lower the supporting bracket slightly by removing some of the $\frac{1}{32}$-inch washers under the bracket or by filing the spacers slightly, so that the chain will be tight when the unit is in the lowest possible position.

Wires are subject to dislodgement and injury, hence they should be examined carefully to see that they are not resting on sharp edges of metal and that the insulation is not worn or injured. See that none of the wires are swinging or rubbing against metal, as this is likely to injure the insulation. Also examine the cables leading through the battery box and mud guards; the bushings must be intact and in place to protect the cables from short-circuiting. Wherever injury to any part of the insulation is found, wrap the spot carefully with insulating tape and bend away from the metal to provide sufficient clearance to prevent further damage.

If the lamps fail to light when the lighting switch is operated, the fuse on the back of the lighting switch should be examined; it may be burned out, broken, or not properly clamped in its fuse clips. The wires may not be properly connected (this should be checked by wiring diagram), the bulbs may be burned out, or the filaments may be broken. The lamp wiring may be short-circuited or the charging circuit may be open.

Do not run the engine with the battery disconnected or off the car without first insulating or removing two of the generator brushes to prevent the generator from generating a current. To determine if generator is operating properly, turn on the head and tail lamps while the engine is idle. Start the engine and accelerate to charging speed or over; a perceptible brightening of the lamps will indicate that the machine is generating sufficient current both to charge the

battery and to light the lamps. Do not open the charging circuit at any time when the engine is running.

Testing Generator with Ammeter. A more accurate determination may be made by connecting an ammeter in the circuit. Disconnect the red and green wire connected to the fuse terminal on the back of the lighting switch and connect it to one terminal of the ammeter. From the other terminal of the ammeter, connect a wire to the fuse terminal to which the red and green wire was previously connected. Turn the lights on with the engine idle. The ammeter should register "discharge", the reading representing the amount consumed by the lamps turned on, i.e., head and tail lamps, 5 to 6 amperes; side and tail lamps, $1\frac{1}{2}$ to 2 amperes. If the ammeter indicated "charge" instead of "discharge", with the lamps turned on and the engine idle, reverse the wires connected to the ammeter terminals. In case the ammeter does not register, see that the pointer is not jammed, otherwise, the circuit is open at some point or the battery is exhausted.

Run the engine at a speed corresponding to 12 to 15 miles per hour, the lights being turned off. If the ammeter registers "charge", the generator is then charging the battery. Increase the engine speed to a car speed corresponding to 13 to 18 miles per hour. The ammeter reading should then be from 12 to 15 amperes. As the engine speed is increased above 18 miles per hour, the charging rate will decrease gradually to approximately 10 amperes at very high speed. With the engine running at 12 miles an hour or faster, turn the lights on; the charging rate should drop according to the number and size of the lamps turned on (see current consumed by each lamp as given above). Turn the lights off and, while permitting the engine to slow down, observe the ammeter. It should drop to zero at approximately 0- to 2-ampere charge.

HEINZE-SPRINGFIELD

Preliminary Operations. Before beginning the installation, adjust the ignition and the carburetor so that the engine is working efficiently. Remove the radiator and the radiator tie rod; disconnect the water-inlet pipe from the side of the cylinder, but do not break the hose connection; also disconnect the water-outlet pipe from the upper forward end of the cylinder block. Remove the priming wire that protrudes through the front of the radiator and is connected to the

carburetor; disconnect the wires from the headlights, first removing the plugs from the sockets; and disconnect the wires from the connecting plugs. The radiator can now be lifted from the frame. After it has been removed, disconnect the water-outlet pipe from the hose and discard the latter. Remove and discard the ground-wire connection of the Ford lighting system, which will be found soldered to the lower left-hand corner of the back side of the radiator.

Remove the fan and the starting crank and the fan pulley. To take off the pulley, first remove the two cotter pins from the pin holding the fan pulley on the end of the crankshaft. Throw the speed lever in gear (allowing it to go forward to engage the clutch) and push the car forward or backward enough to turn the motor over so that the pin is in a vertical position, which will permit driving the pin down through the hole in the engine frame. Then remove the fan pulley and discard it with its starting pin and cotters.

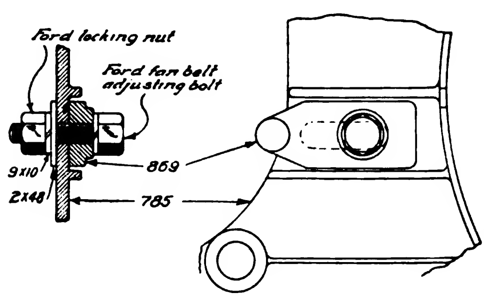


Fig. 395. Correct Assembly for Belt Tightener for Heinze-Springfield Ford Installation

Disconnect the advance rod from the timer case, placing the rod to the right to keep it out of the way of subsequent operations. Take out the cap screw running through the breather pipe. This will release the spring holding the timer housing in place, and the timer housing can be lifted off. Place it to the left, *but do not disconnect the wires*. Note carefully the position of the timer, or commutator-brush assembly, and then remove it from the camshaft by taking off the nut, the small steel brush cap, and the retaining pin holding the brush assembly to the shaft. *Do not turn the motor over while the timer brush assembly is off, and be sure to replace it in its original position when reassembling.* In this way the timing of the engine will not be deranged.

The timing gear, or cylinder front cover, should then be removed, retaining all the bolts, the nuts, the gaskets, and the cotter pins, for replacement in mounting the main-bracket plate 785 of the Heinze equipment, Figs. 395 and 396. It is necessary that the felt washers

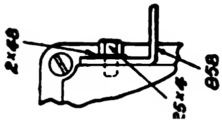


Fig. 396. Heinze-Springfield Starting Motor and Generator Unit Installed on Ford Engine
Courtesy of John O. Heinze Company, Springfield, Ohio

in this timing-gear cover around the crankshaft and the camshaft be removed and inserted in the corresponding positions on the new main bracket plate which takes the place of this cover. In case the car has seen considerable service and these felt washers are worn, it is advisable to replace them with new ones; otherwise, there will be a dangerous leakage of oil from the crankcase.

Secure the water-outlet header 834, Fig. 396, in place on the cylinder-head casting, using the original Ford bolts and gasket. Place the fan-belt tightener 865, Fig. 395, with the nose away from the large gear housing, in the slide provided for it on the main bracket plate 785. Remove the fan-adjusting screws and the locking nut from the Ford timing-gear housing plate and use them together with the two lock washers (9×10) and the plain washer (2×48), as shown in Fig. 395. Set the main bracket plate in position on the engine and bolt it securely in place, using the original paper gasket, the cap screws, the bolts, the nuts, and the cotter pin. Then bolt the main bracket plate 785 to the water-outlet header 834, using the two bolts (26×1), the lock washers (9×10), and the plain washers (2×48), Fig. 396. The commutator-brush assembly and the housing should now be replaced, taking care to put them in their original positions; then connect the spark-advance rod on the commutator housing.

Installing the Unit. *Generator-Motor.* The generator-motor unit should now be placed in position on the main bracket plate with the chain-adjusting stud 829 in place on the unit. This chain-adjusting stud should rest freely in the bottom of the slot at the top of the main bracket plate. Assemble on this chain-adjusting stud 829, the plain washer (2×44), the lock washer (9×12), and the nut (20×13). Place the lower adjusting bolt 868 in the slot provided for it on the main bracket plate. A lock washer (9×12) and a nut (20×13) are provided for this bolt. Place these in their respective positions, but do not tighten either the upper or the lower chain-adjusting bolts at this time.

With the unit loosely in place, proceed with the chain equipment as follows: Place the generator-shaft spacer 856 and the Woodruff key (21×9) on the generator shaft, Fig. 396. Place the gear and the sprocket assembly 919 also on the generator shaft, so that the large gear is on the inside toward the main bracket plate. Place the chain

811 around the sprocket 776 and also around the small sprocket on the generator shaft, taking particular care that the open side of the crankshaft sprocket is toward the front of the car. With the two sprockets and the chain in this position, slide the crankshaft sprocket 776 and the gear and the sprocket assembly 919 into place on the crankshaft and on the generator shaft, respectively, taking care that the starting-pin hole in both the crankshaft and the crankshaft sprocket 776 are in alignment. Insert the starting pin 814 with the counterbore of the cotter-pin holes toward the front of the car. These holes are also to line up with the two corresponding holes in the rear wall of the crankshaft sprocket 776. When the two cotter pins (3×7) are inserted, it is necessary that they be placed *clear through and bent over flat against the rear face of the crankshaft sprocket 776*. Unless secured in this manner, Fig. 397, there is great danger of the cotter pins breaking off and allowing the starting pin 814 to come out. *This will result in serious damage to the entire system.* By means of the fillister-head cap screw (25×1), Fig. 396, in the upper chain-adjusting stud 829, raise the generator-motor unit until the chain is reasonably tight. Then securely lock it in position by tightening the upper and the lower holding-stud nuts (20×13). The generator-motor unit and the driving-chain equipment are then securely installed.

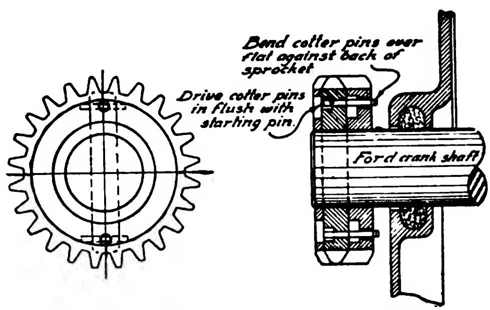


Fig. 397. Correct Heinze-Springfield Assembly of Crankshaft Sprocket

Chain Drive. The chain cover 832 is next to be placed in position, Fig. 396, using the cap screws (26×5) and the lock washers (9×9) to hold it securely to the main bracket plate. Place one of the fan-belt guards 841 on the generator shaft, with the three projections toward the front of the car. Then assemble the fan-belt pulley 828 against this guard and complete the fan-belt pulley assembly with the other fan-belt guard 841, this time, however, placing the three projections toward the rear of the car. These projections serve as centering points for the guards on the fan pulley, and the guards must

be assembled with the projections toward the pulley. This assembly should be locked securely to the generator shaft by the use of the plain washer (2×44) and the castellated nut (14×5). The cotter pin (3×7) must then be placed through the end of the shaft to lock this nut. Next install the motor rear-stiffening bracket 858 on the motor-brush head, using the bolt (25×4) and the washer (2×48) under the bolt head. Do not tighten this bolt until after drawing down the cylinder-head bolt securing the bracket to the engine.

Over the old Ford fan pulley assemble the two half pulleys 784, using the screws 804, the lock washers (9×6), and the nuts (13×12), Fig. 396. By this means, the fan belt runs closer to the fan blades than before. Now mount the fan in position on the main bracket plate 785, using the original Ford screw. Place the lock washer (9×12) between the Ford fan bracket and the main bracket plate, to lock the fan bracket securely in place. Adjust the new fan belt 836 over the two pulleys to the proper tension.

Bendix Drive. Next install the Bendix drive 812 on the starting-motor shaft, Fig. 396. Remove the drive bolt of the Bendix unit and place the latter on the shaft; then replace the drive through the hole in the end of the shaft and secure by means of the lock washer and the nut, taking care to bend the small projection on the special Bendix lock washer upward against the side of the nut.

Final Assembly. Before replacing the radiator, put back the hand crank and turn the engine over several times by hand to note that everything is properly installed and operates freely. Solder one end of each headlight ground wire to the inside face of the radiator, bringing the wires out through the holes provided for the headlight wiring, and be sure to allow sufficient wire to reach the headlight sockets. Then replace the radiator, using all the original bolts, nuts, gaskets, and cotter pins. It is advisable to turn the fan blades over slowly by hand before using the starting crank to make sure that the blades do not interfere with any part of the starting system or with the radiator. It is advisable to replace the hose connections of the radiator with new ones, and they must be tightened up very carefully to guard against leaks. When refilling the radiator, it should be noted whether there is the slightest sign of a leak and, if there is, it should be corrected at once, as any water falling on the starting system will injure it.

Switch and Wiring. Remove both the front and the rear floor boards from the car. About one inch to the right of where the steering post passes through the dash, there is a hole in the toe board, which was originally provided for the horn tube. Remove this board and enlarge the hole to the left about 1½ inches, using this hole to bring the wiring through from the motor to the switch. Remove the Ford "magneto to coil" connection and also the "switch to terminal wire" connection and discard both of them. Also remove and discard all of the old headlight wiring. With the switch bracket in hand, see that the stay rod is screwed in flush with the face of the bracket. Next place the switch in the bracket so that the "off" position of the switch is on top, or nearest the switch-bracket flange. Fasten the switch securely to the switch bracket by means of four flat-headed screws.

Take the complete wiring assembly as received, enclosed in the 13-inch length of the circular loom, and, with the switch mounted in the switch bracket, connect the wires, being careful to assemble the proper terminals on the proper binding posts, Fig. 398, as follows: one large wire with the terminal *SM* on the post *SM;* one large wire and one small wire *SB* on the post *SB*. There then remain three small wires with the terminals *C*, *M*, and *L*, which are to be placed under the heads of the spring-terminal posts bearing the corresponding letters. The spring terminal *AM* is for the ammeter only.

Assemble the switch and the bracket on the dash. By use of the two switch-bracket clamps, the fillister-head screws, and the lock washers, fasten the switch bracket to the dash, slightly to the left of the steering post, in such a position that the hole in the end of the stay rod will line up with the Ford body bolt. Remove the nut from this bolt and clamp the stay rod securely. The foregoing instructions refer to the Ford touring car, the runabout, and the coupelet models.

In the case of the sedan model, by the use of three round-head blued wood screws, fasten the switch bracket to the dash, slightly to the left of the steering post, in such a position that the hole in the end of the stay rod will line up with the Ford body bolt. Remove the nut from this bolt and clamp the stay rod securely. This is a special stay rod 943 and is supplied only for the sedan model, so that the latter must be specified in ordering.

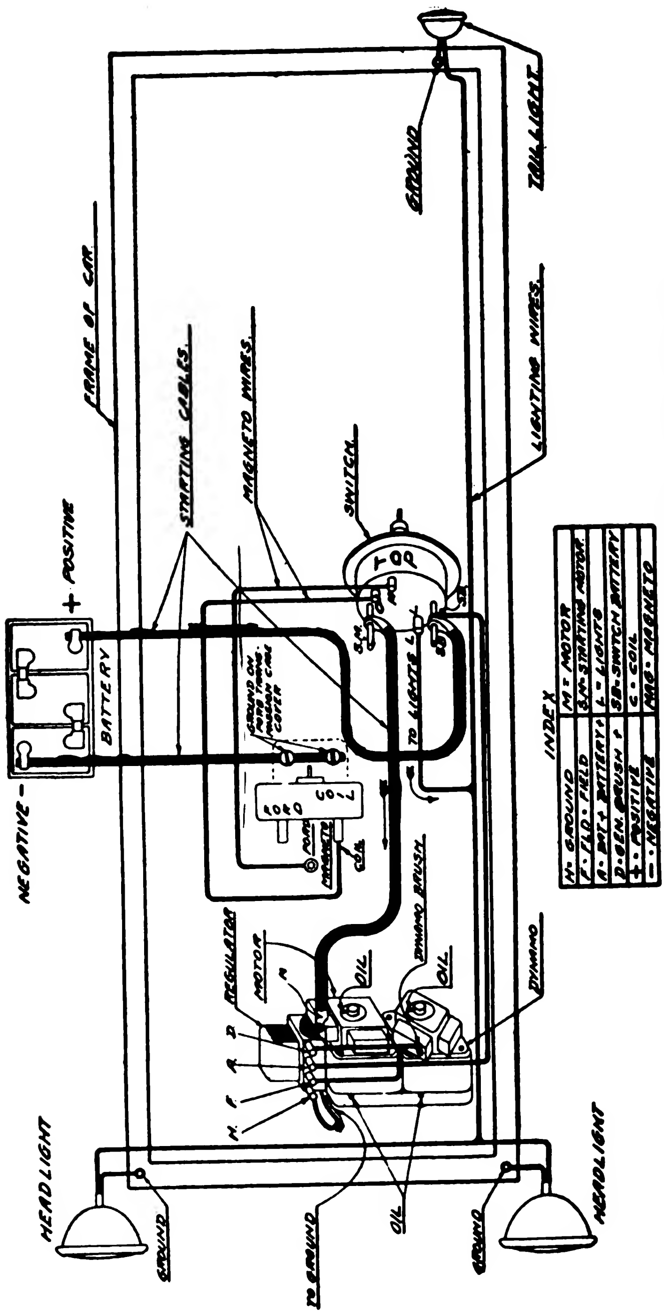


Fig. 398. Wiring Diagram of Heinse-Springfield Ford System without Ammeter or Dash Lamp

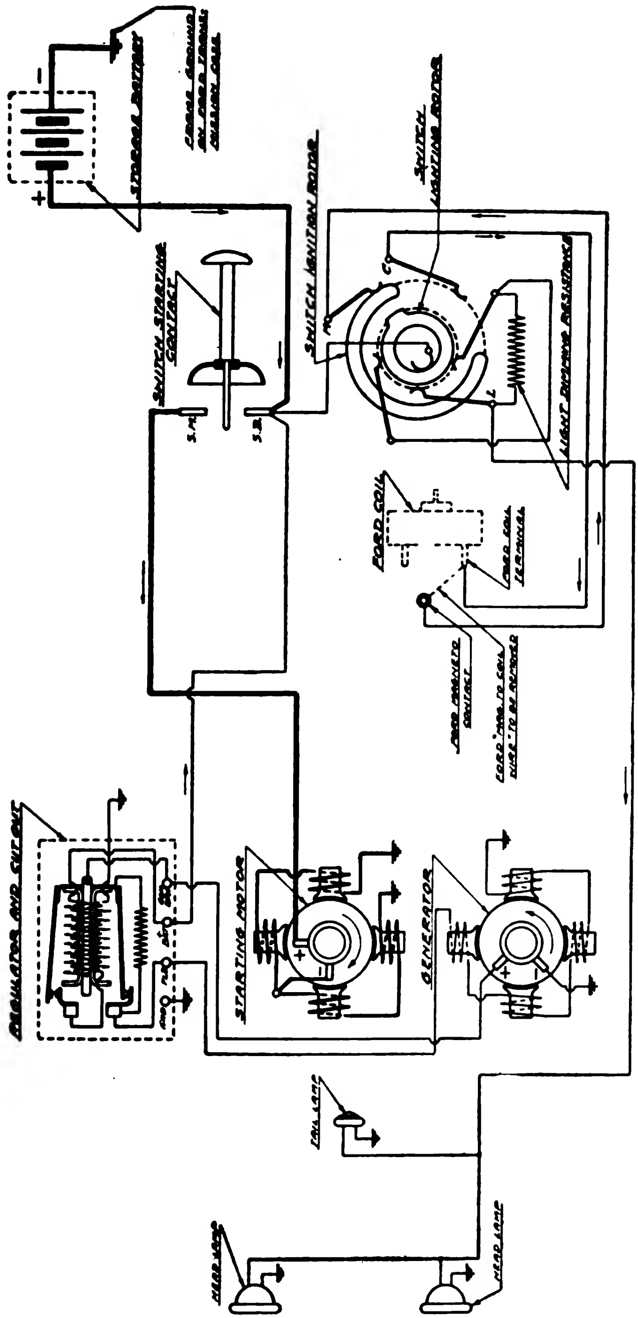


Fig. 399. Wiring Circuit of Heinse-Springfield Ford System without Ammeter or Dash Lamp

Coil and Magneto Wiring. Extending through the 13-inch length of the circular loom are two wires, one end of each being connected to the spring terminals *C* and *M* on the back of the switch, Fig. 398. Connect the wire from the terminal *C* to the magneto terminal on the rear of the Ford coil box; connect the wire from the terminal *M* to the magneto contact on the flywheel housing. These two terminals were formerly connected by the Ford "magneto to coil wire", which has been discarded, Fig. 399.

Charging Wire and Starting Cable. On the back of the switch on the post *SB* are connected one large and one small wire, Fig. 398. The small wire is to be connected to the terminal on the regulator *A*. On the back of the switch on the post *SM* is connected the "switch to starting motor" cable, on the other end of which the terminal *M* is to be connected to the upper, or positive, starting-motor brush.

Wiring for Lights. On the back of the switch on the spring terminal post *L* is connected a lighting cable, which is to be connected to the headlights and the tail light, Fig. 398. Three wires are provided which are to be used to ground one side of each light. To ground the tail light, run the ground wire under the tail-light frame bolt. If an oil lamp is used, tape the end of the light wire which is provided for an electric tail light and secure it to the tail-light bracket, so that if the electric light is subsequently installed, the wiring will be there for it. Secure the lighting cable to the car frame at several convenient points to keep it free from oil and to prevent chafing, which would cause grounding of the lighting circuit. When single-contact lamps are used, ground wires are not necessary, as one side of the lamp socket itself is grounded.

Battery Cables. Before connecting the positive (+) battery terminal to the switch terminal and the negative (−) battery terminal to the ground cable, be sure that the switch is in the "off" position. Then connect these wires as follows: Under the front floor board is the Ford transmission-case cover which is held in place by six bolts. Remove the upper right-hand bolt and assemble under this the starting-cable clamp. From the post *SB* on the back of the switch, Fig. 398, run the positive battery to the switch cable, placing it under the starting-cable clamp. Pass this cable through the circular loom placed between the running-board apron and the bottom of the body,

and through the hole in the battery box to the positive terminal of the storage battery.

Remove the two lowest bolts on the transmission-case cover and clean the transmission-case cover with a piece of sandpaper or emery cloth to insure a good electrical contact at this point. Under these bolt heads, assemble the brass ground strip on one end of the negative of the battery to the ground cable and run the other end through the circular loom mentioned above, then through the hole in the battery box to the negative terminal of the storage battery. Tighten these wires securely to the storage-battery terminals, using pliers for this purpose.

Installing the Battery. On all the different types of Ford cars, the battery is placed on the right-hand running board, midway between the front and the rear fenders, particular notice being taken that the battery box does not interfere with opening the door. In the bottom of the battery box are six holes, the four inside holes being provided for the four carriage bolts holding the battery box on the running board, and the two outside holes being provided for the two battery hold-down rods which hold the storage battery securely in place. Six corresponding holes $\frac{5}{16}$ inch in diameter must be drilled in the running board, to correspond to the six holes in the bottom of the battery box. Two wood pads are provided, which are to be placed inside the battery box. Two steel reinforcing pads are also provided, which are to be used under the running board. Place the four carriage bolts down through the wood pads, the battery box, the running board, and the steel pads, and clamp by means of carriage-bolt nuts. Next place the storage battery in the battery box with the positive (+) terminal toward a rear of the car, and by means of the hold-down rods which are hooked over the handles of the storage battery, fasten securely, using lock washers and nuts.

At a point midway between the two wire holes in the battery box, pry down a part of the running-board apron with a large screwdriver or a pinch bar, providing sufficient space between the running-board apron and the bottom of the body for the four-inch length of the circular loom through which the two battery cables pass.

Choker, or Priming-Rod, Assembly. On the air-gate lever of the carburetor, connect one end of the choker cord under the outside bolt which connects the carburetor and the inlet pipe, assemble

the choker loop in a vertical position, and pass the choker cord through the upper loop. On the dash, to the left of the carburetor adjustment, drill a ¼-inch hole. Through this hole pass the other end of the choker cord and connect the choker ring. This choker assembly displaces the Ford choker wire (carburetor-priming device), which extends through the radiator before the starting system has been installed. It is used to shut the air supply from the carburetor, so as to increase the suction through the carburetor nozzle and facilitate starting.

Tail and Side Lights, Horn, Etc. The use of an electric tail lamp is not necessary to the operation of the system. Provision has been made for an electric tail lamp, which is not furnished with the equipment, but, owing to the small additional cost and its great convenience, its use is advised. It should be wired as shown in the wiring diagrams, Figs. 398 and 400. If a single-contact tail lamp is used, it is not necessary to employ the ground wire, as one side of the lamp socket is already grounded to the car frame. In as much as there is emobdied in the lighting system a light-dimming resistance for the headlights, which is governed by the combination switch, it is not advisable to convert the oil side lamps to electric. The horn supplied on the Ford (No. 196 and later models) car is operated by the alternating current from the magneto. This horn may be used without interfering with the starting system, but cannot be operated by the storage battery. If desired, a direct-current horn may be installed and should be connected as shown in Figs. 400 and 401.

Ammeter and Dash Lamp. These are not furnished with the system as described, but may be had at an additional cost. This equipment consists of a switch bracket and an ammeter reading to 30 amperes, charge and discharge; a single-contact dash lamp with a self-contained switch and all the necessary wiring. In order to connect the ammeter in the charging circuit, there must be a spring binding post on the back of the combination switch *AM*, Fig. 400. All of the later combination switches of this make are fitted with this binding post. On the back of the combination switch, from the spring binding post *AM* to the round-head screw, there is connected a small flat brass strip. Break this strip connection by cutting in the center, using the pliers or a hack saw. Connect the ammeter and the dash lamp in the circuit, as shown, being very careful to connect the wire

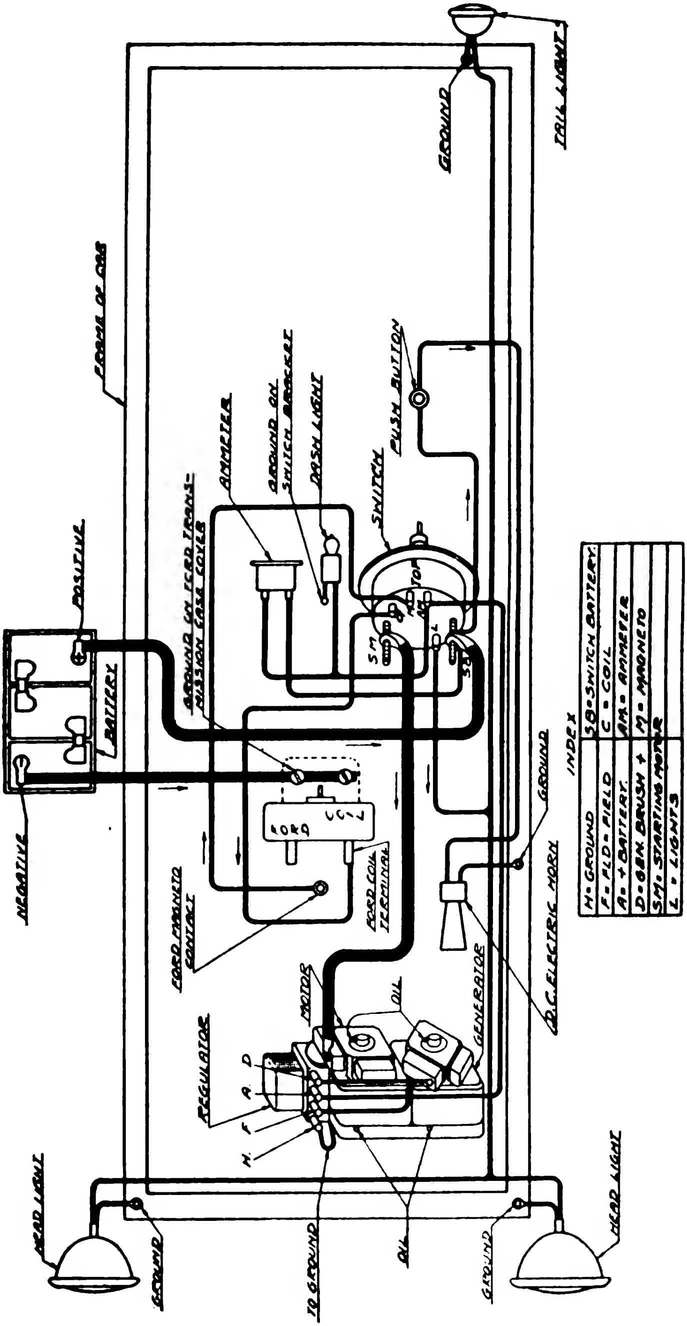


Fig. 400. Wiring Diagram of Heinse-Springfield Ford System with Ammeter and Dash Lamp

from the post SB to the "discharge" side of the ammeter and the wire from the spring binding post AM to the "charge" side of the ammeter. One end of the charging wire, running from the battery positive terminal of the regulator and the cut-out to the terminal SB on the back of the switch, must be changed over from the terminal SB to the binding post AM, Figs. 398 and 400.

Testing and Operation. Place the brake lever, the spark, and the throttle levers in the usual starting position, then unlock and rotate the combination switch lever to any of the three positions desired, as follows: "lights off, ignition on"; "lights dim, ignition on"; "lights bright, ignition on". Depress the starting button in the center of the combination switch. This sends the current from the storage battery through the starting motor, and the rotation of the starting motor causes the small gear on the Bendix shaft to mesh with the gear on the generator shaft. Riveted to this gear is the sprocket over which the silent chain runs. During the interval that the starting motor is in operation, a heavy current is drawn from the storage battery, and, if the lights are on, there will be a perceptible dimming caused by the decrease in the battery voltage. This is especially noticeable when the battery is nearly discharged, and will also be more apparent when the engine is stiff and hard to crank, or when there is a loose connection in the battery circuit. Although a fully charged battery is capable of cranking the engine for several minutes, it is not advisable to continue cranking longer than a few seconds, owing to the heavy discharge. If the engine does not start in this time, the choking device should be used to prime the carburetor. Should this not start the engine, investigate the cause before cranking further, as otherwise the battery will be exhausted. Frequent discharging of the battery in this way shortens its life. The front and the rear bearings of the starting motor should be oiled every 500 miles, though the Bendix drive-screw shaft should never be oiled nor lubricated in any way. The screw gear works to the best advantage when the shaft is dry.

As the mounting bracket is bolted to the machined surface of the timing-gear housing of the engine, the silent chain must be kept in good alignment at all times, and it must also be kept sufficiently tight to prevent it from striking the chain guard as well as to avoid the possibility of the chain teeth riding the sprocket, in which

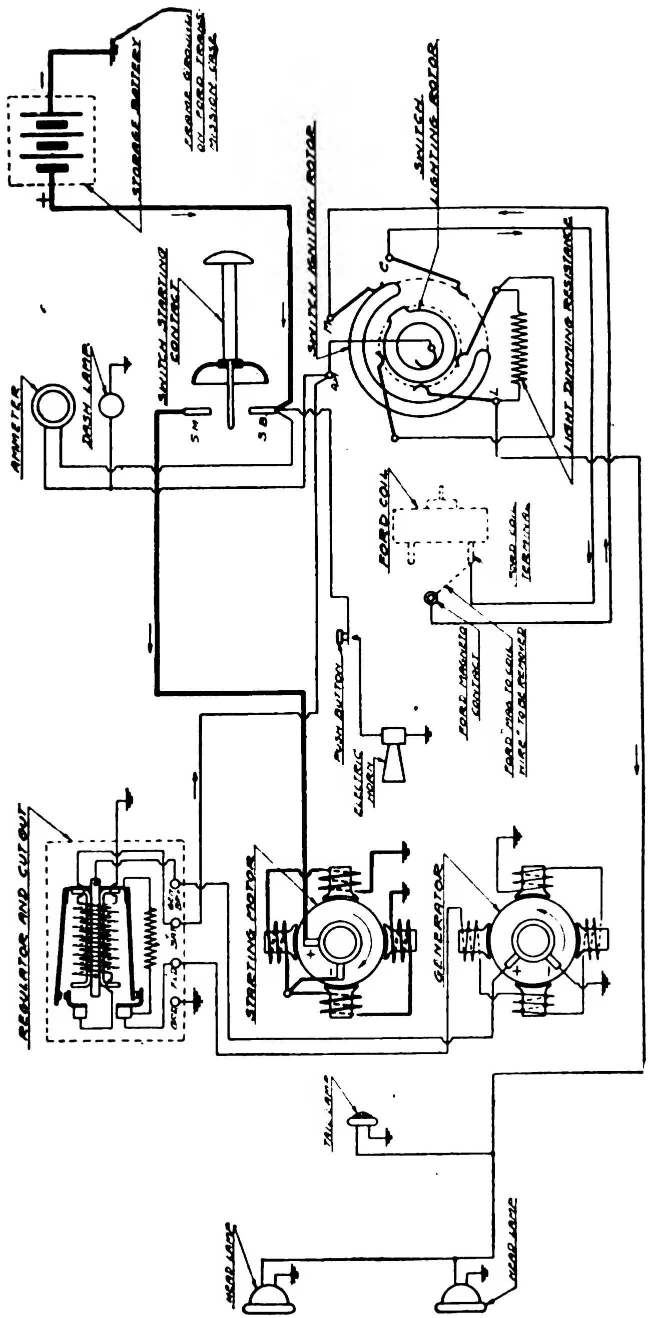


Fig. 401. Wiring Circuits of Heinze-Springfield Ford System with Ammeter and Dash Lamp

case the chain will break because of the severe strain placed upon it. The battery cut-out is designed to close when the car is traveling about 6 miles per hour, at which speed the charging current is about 4 amperes, increasing rapidly to 10 to 12 amperes at 10 miles per hour. After the car has been run the first hundred miles with the starting system in operation, the chain should be adjusted to take up the slack caused by the stretch; after that it should be inspected about every 300 miles. The operation of the regulator and the care of the system is given in detail in connection with the general descriptions, in alphabetical order.

FISHER

Preparing Engine. This is a twelve-volt two-unit type, the two members of which, for convenience in mounting, are combined as a

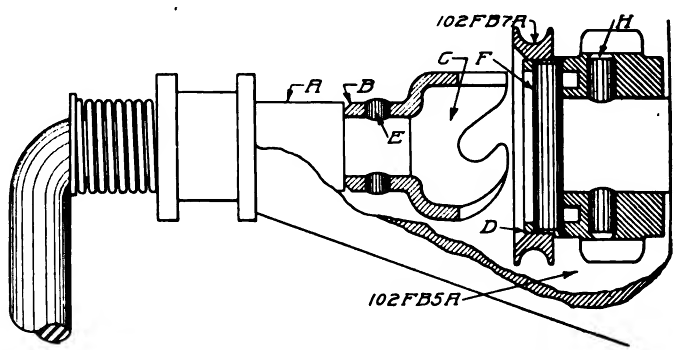


Fig. 402. Crankshaft Pin and Sprocket on Fisher Ford Installation

single mechanical unit. To install, the radiator, the water connections, the fan, the starting crank, and the fan pulley on the crankshaft must be removed. The lower water connection, or elbow, at the side of the cylinder block need not be taken off, but must be loosened. Place the new sprocket 102FB5A, Fig. 402, on the end of the crankshaft, driving the pin *H* through the cross-hole in the end of the crankshaft, burring the pin slightly so that it cannot drop out. This secures the sprocket to the engine crankshaft. The pin *F* is placed in the sprocket before shipment.

Then slip the pulley 102FB7A over the end of the sprocket up to the shoulder. Secure the pulley by several center punch marks between the end of the sprocket and the internal diameter of the pulley at *D*. If it is desired to retain the Ford starting crank in place

(this is preferable to carrying it in the tool box), cut $\frac{3}{16}$ inch off the crank ratchet *C*, Fig. 402, at the shoulder *B*—the original hole in the crank ratchet *C* and the starting crank are not disturbed. If there are burrs on the crank ratchet or if it is too large to enter the chain sprocket, the tips must be filed off or turned down in a lathe.

Mounting the Starting Unit. Remove the right-hand bolt of the top water connection 102FB16, Fig. 403, and the second bolt on top of the cylinder 102FB12. If there are rough places on the casting under these bolts, they must be removed. Take from the starting unit bracket 102FB3 and place the bracket in the position shown in Fig. 403. Between the bracket 102FB3 and the water connection is placed a heavy steel spacing washer. The bracket must be bolted securely in place against the water connection by the bolt 102FB12. The careful placing of the bracket and the clamping of these bolts is essential to the successful operation of the installation. After the bolts mentioned are securely in place, turn the set screw 102FB10 until it rests securely and firmly on the engine casting and, when it is firmly bedded, lock it securely by screwing home the lock nut. The purpose of this set screw is to take care of the stresses between the shaft of the generator and the crankshaft of the engine; note that the end of the screw must rest on the casting, otherwise the driving chain may be injured.

Place the starting unit 102S1A on the bracket and clamp it in its lowest position with the nuts on the studs. A long-shank T-wrench is the handiest to use for this work. The chain, which is coupled with a bolt and a cotter pin, may now be put in position. Roll the chain under the sprocket 102FB5B and on the sprocket 102FB13 on the electric unit. Bring the links together and slip the bolt through toward the radiator and put the washer and the cotter pin in place. Tighten the chain by loosening the nuts, Fig. 403, holding the starter to the bracket and the nuts 102FB18, then turning the set screws 102FB11 up until the chain feels taut when pressed with the fingers. Tighten the bracket nuts and the lock nuts 102FB18. Turn the engine over a few times with the starter and tighten the chain again. This should be repeated after the car has been in use a few days. The life and the service of the chain will be greatly increased by keeping the proper tension on it, particularly during the first few days it is in use, when it is stretching.

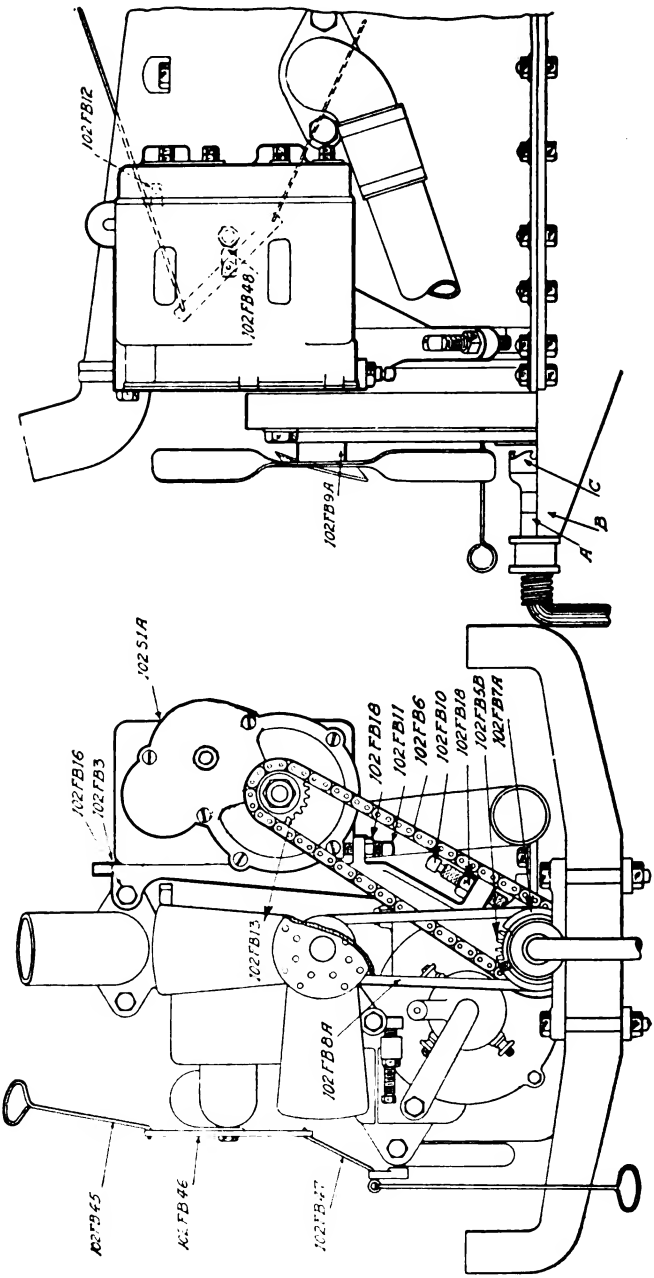


Fig. 403. Front and Side Elevators of Fisher Ford Starter

Separate the split pulley 102FB9, Fig. 404, and the clamp on the shaft of the fan between the brass pulley and the fan blades by the two screws. The diameter of the bore of this pulley is slightly less than that of the neck of the fan so that it may be filed down with a round file to fit the neck of the fan pulley. When this pulley is in position, hook the round belt 102FB8A, Fig. 403, furnished with the equipment, over the pulley on the crankshaft and the pulley on the fan.

Remove the plug from the top of the electric unit and, with the aid of a grease gun, squirt one-half pint of good transmission grease into the gear case of the unit, and then replace the plug. This will lubricate the gears for a period of six months.

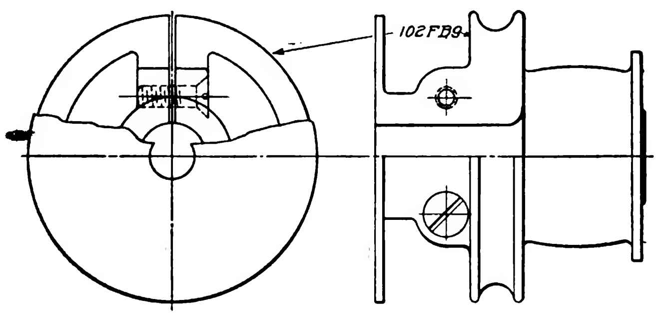


Fig. 404. Part Section of Fisher Split Pulley

Battery and Wiring. The battery box may be located on either running board as convenience dictates, holes being drilled in the apron to pass the battery cables. Place short pieces of $\frac{1}{2}$-inch "flexduct", or circular loom, in the wiring holes through the battery box and the metal apron of the car and the 1-inch flexduct between the transmission cover and the engine hanger on the left and let it extend back past the brake pedals. Place the instrument board carrying the ammeter, the lighting switch, the starting switch, and the dash lamp, under the cowl dash to the left of the steering column. The length of the wires necessary to connect the battery to the various essentials can now be measured to suit this particular installation.

Run the large negative starter cable from the negative (−) post of the battery through the flexduct insulation in the battery box and by the transmission case to the negative post on the motor. From

the positive terminal of the battery, run a cable through the flexduct insulation to the binding post of the starting switch, as shown in Fig. 405; from the other binding post run a cable to the positive brush holder of the motor. The terminals on these cables should be soldered, and the binding posts tightened with a wrench. (Whenever soldering has to be done on electric wires, use a noncorrosive flux and *not an acid*, as the latter not only is an electrical conductor but will also corrode the joint surfaces.)

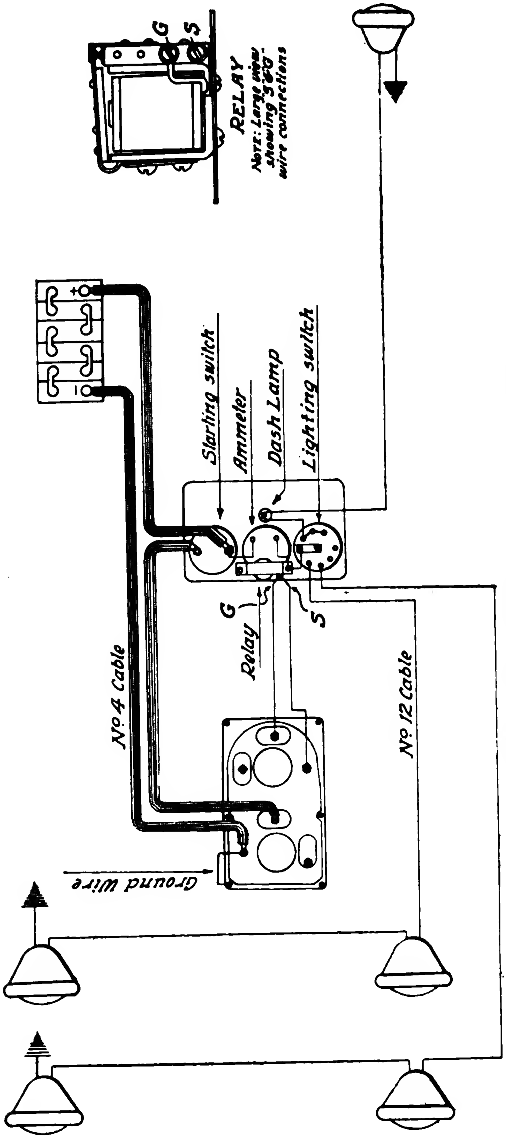


Fig. 405. Wiring Diagram for Fisher Ford Installation

Run the lighting cable from the lower brush *G* on the starting unit and connect to the terminal *G* on the relay. Connect another lighting cable from the post *S* on the generator to the post *S* on the relay. Run a lighting cable from the lighting switch to the side lamps, as shown, grounding one side on some metal part of the chassis. Take the wire running to the headlights from the original push-button switch on the car and connect it to the proper binding post on the new lighting switch. Connect the lighting cable

from one side of the dash lamp to the tail lamp, grounding one side of the tail lamp, as shown. When the wiring is finished as above outlined, test each circuit, making certain that all the connections have been made in accordance with the wiring diagram, Fig. 405. Solder and tape all the joints, and tighten all the terminals with a wrench. Close the ignition switch, press the starter button, and the engine should be turned over by the starting unit. As soon as the engine begins to run at a fair speed, the ammeter should indicate a charge going into the battery. Then stop the engine and turn on the lights; the ammeter should then show a discharge reading.

Operating Instructions. As is the case with the majority of Ford starting systems, the choker wire to the carburetor is taken from the front of the radiator and carried up through the dash. In cold weather it is always advisable to pull this wire and flood the carburetor when starting. Driving the starter with a loose chain is dangerous and should be avoided, so that the tension of the chain should be inspected at regular intervals until it has seen sufficient service to have stopped stretching. The starter—that is, the generator—must not be run with the battery disconnected unless the small wire *S* is removed from the binding post on the generator. No attempt should ever be made to start with the spark lever advanced. Instructions for the care of the brushes and the commutator, the location of short-circuits, grounds, and the like, will be found to be the same as those outlined in connection with the description of other Ford systems.

NORTH EAST

Preparing Engine. While a single unit of the chain-driven type, this differs from the others of this type already described only in the details of the chain drive. Remove the radiator and the water connections, the fan, the fan bracket, the screw for adjusting the fan, the fan pulley on the crankshaft, the starting crank, the timer rod for the advancing and the retarding ignition timing, one bolt holding the gear-case cover to make place for the stud 2394, and five bolts on the lower flange of engine base to make place for the bolts 2369, Fig. 406. Before removing the timer rod, carefully mark the timer housing and place a corresponding mark on the timing-gear case in order that the ignition timing of the motor may not be altered when the new timer rod, provided with the North East equipment, is installed.

Mounting Starter. The numbers for the various parts given in the following instructions for installing the unit, all refer to the illustration, Fig. 406. Place the chain sprocket 2374 on the crankshaft and fasten with the pin originally used for holding the Ford fan pulley; replace a split cotter pin in each end of the large pin for locking purposes, as in the original mounting. Then replace the starting crank. Screw the stud 2388 in place and lock it by passing a split cotter pin through the hole at the inner end. Be sure that the shoulder of this stud is brought up tight against the finished face on the timing-gear housing (casting), so that the stud will be in absolute alignment with the crankshaft.

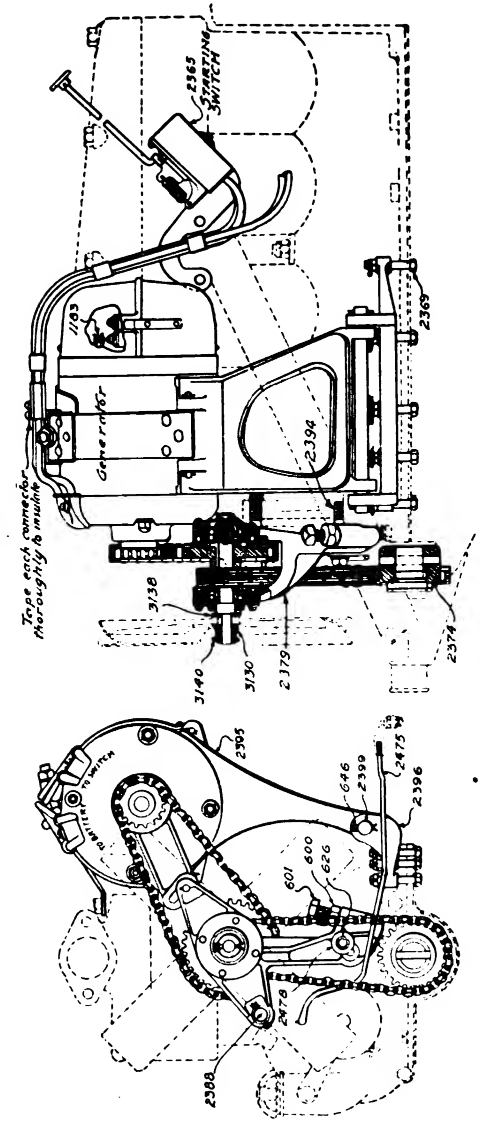


Fig. 406. Front and Side Elevations of North East Ford Installation
Courtesy of North East Electric Company, Rochester, New York

Screw the stud 2394 in place and lock it with a cotter pin. If the boss of the timing-gear housing at this point is rough, it should be smoothed down with a file before screwing home the stud. Fasten the hinge bracket 2396 by five bolts 2369, inserting them from below, and lock the nuts used on these bolts by split cotter pins; then assemble the cradle 2395 with the generator-motor unit in the hinge

bracket, being sure to place the split cotter pins at each end of the hinge pin 2399 for locking purposes.

If necessary to clear the sprocket bracket, chip off a slight amount of the vertical rib on the gear cover of the engine directly over the crankshaft bearing. Mount the assembled sprocket bracket 2379 on the studs 2388 and 2394. Be sure that one washer 2478 is placed on the stud 2388 before mounting the bracket; pay strict attention to see that there is no clearance between the shoulder of the stud and the bracket. If necessary, place filler washers on this stud so that no strain will be placed on the bracket when the nut on the clamp stud 2394 is securely fastened. *It is very necessary that the chain sprockets be in absolute alignment. Be sure to use a straightedge to make certain that the sprockets line up accurately.* This is very important. To take care of any longitudinal variation; filler washers are supplied for placing on the mounting studs between the sprocket bracket and the shoulders of the studs. These filler washers should be used if necessary to bring the sprockets into proper alignment. After the sprockets have been accurately lined up, mount the timer rod 2475.

Mount the horizontal chain by threading downward over the large sprocket on the countershaft (upper shaft), then around the motor-generator sprocket, and make the connection by inserting the master link from the rear. Then mount and connect the vertical chain in a similar manner. Make sure that the connecting links are properly locked after the loose side plates are in place. Adjust the vertical chain to a moderate tension by relieving the nut on the clamp stud 2394 and screwing down the adjusting screw 601, Fig. 406. After adjustment has been made, be sure to lock the adjusting screw by means of the jam nut and screw down the nut on the clamp stud which has been previously relieved.

To adjust the horizontal chain, release the clasp nut 626 and turn the generator toward the engine. This will take up the slack in the chain. Cut off the fan pulley with a hack saw so that the hub on the fan will be $\frac{3}{8}$ inch long, as shown in Fig. 406. Make certain that the one fiber washer 3138 is first placed on the shaft, then the fan, then another fiber washer 3138, then the two steel washers 3130 with the spring 3140 between them. Pressure should be applied to compress the spring until the cotter pin 646 can be dropped through the hole in the end of the shaft. This is important, as it forms a friction

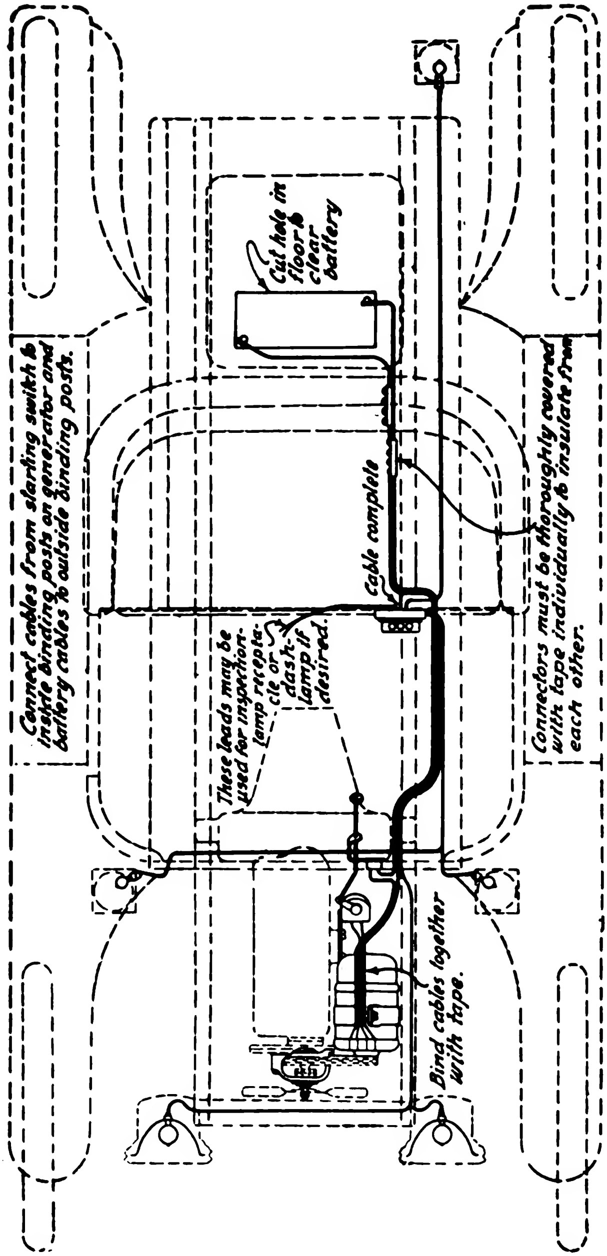


Fig. 407. Wiring Diagram for Complete North East Ford Installation

clutch strong enough to drive the fan and at the same time provides for a certain amount of relief to the sprockets, the chain, and the fan.

Turn the engine over by hand to inspect the working of the chain. Make careful examination to be sure that all the bolts and all the nuts are in place and properly fastened. Oil both the chains with a liberal amount of semi-liquid graphite grease.

Mounting Battery. Install the battery on the runabout, as shown in Fig. 407; on touring cars the battery should be mounted under the rear seat, as far forward as possible. To mount the battery, cut holes through the floor board of the car, large enough to clear the battery. Lay the board 3141, Fig. 408, on the upper face of the lower flange of the frame panels and bolt firmly by using steel clamping strips 3142 placed on the underside of the channel frame. Now fasten the battery in place by means of the hook bolts 2460, being sure

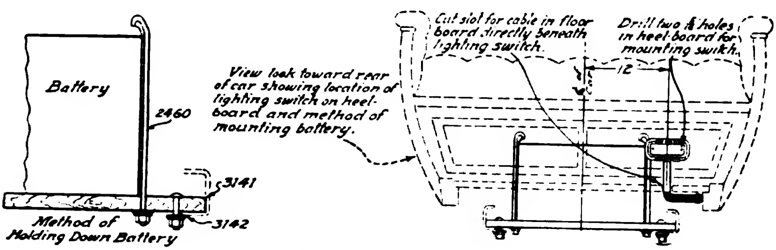


Fig. 408. Details of North East Switch Wiring

that the flat washers and the lock washers are placed between the board and the nuts on the bolts. If the muffler interferes, it is well to cut a groove in the board to clear it and to place a piece of asbestos sheeting between the board and the muffler.

When the car is not already equipped with electric lamps, it will be necessary to install new lights or to mount reflectors in the headlights and adapters, or sockets, in the side and the rear lamps. Mount the lighting switch and run wires to all the lamps and to the battery location, but do not connect the wires to the battery as yet. Also run the wires to the motor-generator, Figs. 407, 408, and 409. Special care should be taken that all the wires are made fast to the wood body and that the insulation on the wires is doubly protected by tape or circular loom where the wires pass through the sheet metal. For fastening the wires, use leather cleats and insulated staples as supplied.

Replace the radiator, taking care not to omit the gaskets and the leather radiator seats, and, at the same time, mount the starting switch 2367, Fig. 406, by the bolts holding the flange of the return-water tube to the engine. After completing this, fill the radiator. Also mount the guide bracket 2368 for the starting button 2366, as shown in Fig. 409. Connect the switch wires to the motor generator, as shown in Figs. 406 and 407. Replace the floor boards, after notching them so as to clear the conduit running from the lighting switch downward. Carefully connect the battery wires to the two wires coming from the general circuit. Connect one lead at a time and carefully wrap the connector with tape before making another connection. Be sure to use plenty of insulating tape over these connections so that they will be well protected. After the connections have been made and insulated, see that the leads are properly fastened. If the wires have to be made longer to accommodate the coupé or the other special bodies, care should be taken to see that the extensions are made of the same size and type of wire that is used in the remainder of the system. Tight mechanical joints, well soldered and taped, should be made. The use of any smaller wire will prevent the proper operation of the system. Where possible to avoid it, the distance between the battery and the electrical unit should never be increased.

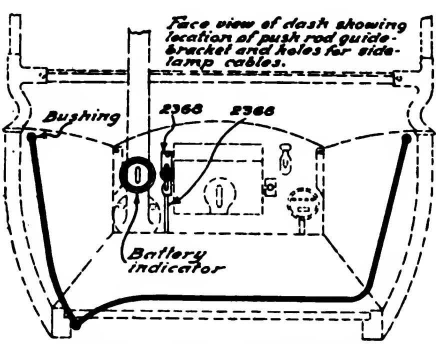


Fig. 409. Details of Dash Wiring for North East System

Operating Instructions. After the car has been run a few hundred miles, inspect the driving chains and, if necessary, adjust to take up any slack. This should be done at intervals until all stretch has been taken out of the chain. Inspect the chains carefully from time to time to see that nothing has disturbed their alignment. The chains should be kept clean by washing with gasoline every few weeks and applying a new supply of graphite grease to their inside faces. To adjust the vertical chain, release the nut on the clamp stud 2394 and screw down the adjusting screw 601, Fig. 406. Be sure to lock this

screw with the jam nut after adjusting. If after adjusting the vertical chain the horizontal chain requires further adjustment, loosen the clamp holding the generator unit and turn the latter in a counter-clockwise direction until the proper tension of the chain is secured, then re-tighten the clasp.

Inspect the wiring from time to time to make certain that none of the connections are loosening up, and when washing the car, see that no water is allowed to fall on the generator or on the wiring. See that the cover on the rear end of the generator is always tight in its place. This cover is detachable for the purpose of inspecting the brushes and the commutator. If necessary to remove the generator at any time, see that the terminals of all the loose wires are well wrapped with electric insulating tape. This is important, since if these wires should come in contact with each other or with the metal parts of the car, a short-circuit may occur and ruin the battery. In disconnecting the wires, be sure to tag them properly so that they can be replaced correctly, as improper connections may damage the system. The battery alone will supply the current for the lamps when the generator is removed from the car, but if used for any length of time with the generator off, the battery will naturally run down and have to be recharged from an outside source; care should be taken not to permit the battery to discharge too low before doing this.

If it should be necessary to run the generator with the battery disconnected from the system, *remove the small 10-ampere fuse 1183, Fig. 406, located over the brushes inside the detachable hood at the rear end of the generator, but be sure to replace this fuse when the battery is again connected.* If at any time the generator is not charging the battery properly, although the system tests out in good condition throughout, it is evident that the fuse 1183 has been blown and should be replaced by a new one of the same capacity. The purpose of this fuse is to protect the generator from injury. The bearings of the generator, when assembled by the manufacturer, are packed with a special lubricating compound, so that no provision is made for oiling them.

The lamps required are 14-volt 18-c.p. G-16½ bayonet-base bulbs for the headlights, and 14-volt 4-c.p. G-8 bulbs with the same type of base for the side and rear lights.

SPLITDORF

Preparing Engine. Disconnect all water and gasoline connections and the radiator brace rod, which should be pushed back through the dash out of the way, and remove the radiator. If the machine is fitted with electric lights, disconnect the wiring, Fig. 410. Remove the fan and its connections and then turn the engine over by hand until the pin holding the fan pulley on the crankshaft is perpendicular. This brings the pin over the hole in the engine base in position to be driven through it. Drive out the pin holding the dog clutch of the starting crank and pull out the crank, Fig. 411. Drive

Fig. 410. Dismounting Radiator Lamps
Courtesy of Splitdorf Electric Company, Newark, New Jersey

Fig. 411. Removing Hand Crank and Fan
Courtesy of Splitdorf Electric Company, Newark, New Jersey

out the pin holding the fan pulley to the crankshaft, and a smart blow on the pulley itself will free it from the shaft. In case the pin is rusted in place, a little kerosene will help to free it.

Remove bolts *B* and *C*, Fig. 412, then loosen the nut *A*, but before removing it from the bolt tie a piece of twine around the bolt to prevent it from falling into the engine base or the crankcase. In case it should drop, it will remain in the hole, and a sharp tap directly beneath it on the crankcase will cause it to jump upward, when it can be caught with the fingers. Place the adjustable bracket in position and secure it to the engine, using new bolts supplied at *B* and *C* with the nuts formerly on the old bolts. The bolts and nuts holding the

lower part of the bracket must be carefully tightened, as it is important that this part be held firmly.

Mounting Starter. Place the split taper sleeve on the engine shaft, using a fine file if necessary to smooth off any burrs. Drive a pin through the sleeve and the shaft until it is flush with the sleeve on both sides. With the key in position, place the sprocket on the sleeve, registering the keyway with the key. A nut is then turned on to draw the sprocket up on the taper sleeve, and it also causes the sleeve to grip the crankshaft securely.

Fig. 412. Placing Adjustable Bracket in Position
Courtesy of Splitdorf Electric Company, Newark, New Jersey

Replace the starting crank, start the chain under the sprocket in mesh, and with the aid of the crank turn the engine over slowly until the chain is drawn through for about half of its length, making certain that the chain is working freely, Fig. 413. Then fasten the generator-motor unit to the adjustable bracket with the three bolts and lock washers furnished. This can be accomplished easily by tilting the bracket. Pass the chain over the generator sprocket, joining the chain with the pin and locking the pin with a washer and cotter pin. Align the crankshaft and generator-motor sprocket by means of the adjustable bracket hinge bolt. Adjust the chain to its proper tension, i.e., without any slack. The chain should never be allowed to run in

a slack condition, as it may break. Adjusting screws on the bracket provide an easy means of keeping it at the right tension.

The fan pulley furnished with the outfit is an aluminum die-casting in two parts and is designed to clamp over the Ford fan pulley. It is held on by four screws and lock washers and brings the center in line for the fan belt. Fill the recess of the fan with grease and replace the fan, using the original bearing stud; place the belt on the fan pulley and on the generator-motor pulley and adjust to proper tension. Like the chain, this pulley should be so tight that there is no undue slack, but tightening it too much should be guarded against,

Fig. 413. Adjusting Driving Chain
Courtesy of Splitdorf Electric Company, Newark, New Jersey

as this only places an excessive strain on the shafts and does not make the fan run any better.

Wiring. The details of the various holes to be drilled or cut and the wiring to be installed are given in Figs. 414 to 419. Prepare the dash for the wiring, as shown in Figs. 415 and 416, which give the location and sizes of all holes—*A*, Fig. 416, for the ignition switch, *B* for the lighting and dimming switch, and *C* for the wires leading to the indicating automatic switch (battery cut-out with indicator to show whether the battery is charging or not). Unless a magneto is used for ignition, *A* may be omitted.

Bore a $\frac{7}{8}$-inch hole in the permanent floor board, as shown in Fig. 414, following the dimensions there given for its location. Install

the starting switch with the front of the switch lengthwise with and facing the right-hand side of the car, Fig. 419, and at the same time

Fig. 414. Details of Wiring for Splitdorf Ford Installation

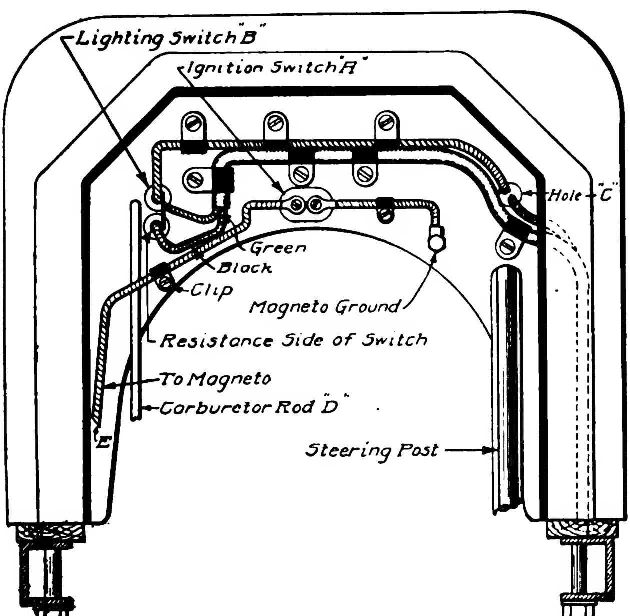


Fig. 415. Details of Wiring on Dash

the light-dimming switch should be placed in position with the coil end of the switch facing down. All wire terminals are marked to

correspond with similar marks on all parts of the installation. Lay wiring assembly in the sill of the car, as shown in Fig. 419, connecting the wires to the front of the dash, as in Fig. 415. (Reference to Fig.

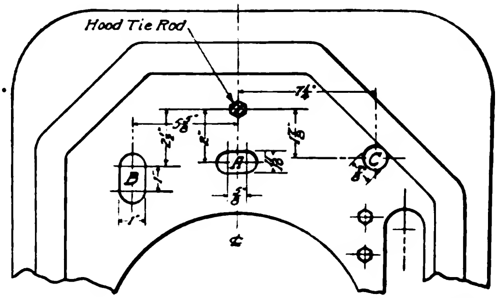


Fig. 416. Layout of Drilling on Dash for Ford Installation

418 will facilitate the installation.) Connect wires to indicating automatic switch in accordance with diagram on the back of the switch, after which fasten the switch to the steering column about 3½ inches from the dash. Connect wires, as marked, to corresponding

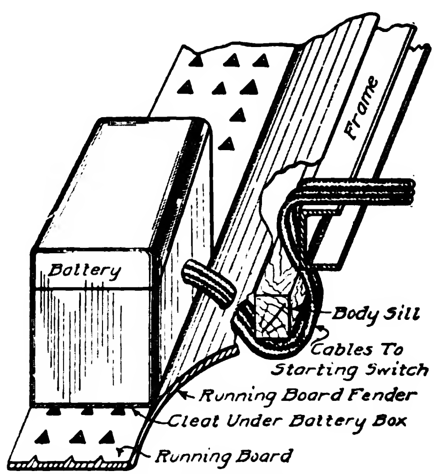


Fig. 417. Method of Running Cables from Batteries on Splitdorf Installation

terminals on the generator-motor and likewise to the starting switch. Prepare the curved running-board guard, or apron, for the battery leads and the running board for securing the battery box in accordance with the instructions given on Fig. 414. Place the battery box

on the running board, resting it on the two wood cleats and fasten it down with the bolts, nuts, and lock washers furnished.

Place the battery in the box with the outside terminals toward the car. Pass the extension cables under the wood sill of the car body and over the channel steel frame of the car, connecting the extension leads from the battery to the starting switch, as marked. The method of passing the cables around the sill and frame are shown in Fig. 418. After connecting the cables to the battery, cover all the

Fig. 418. Complete Wiring Diagram for Splitdorf Ford Installation

terminals and exposed parts of wires with vaseline or grease to prevent corrosion.

Wiring Diagram. In the wiring diagram, Fig. 418, double wiring is used throughout, so that there are no ground connections. When the engine is running so that the unit is operating as a generator, the current flows from terminal $+D$ on the generator to a similarly marked terminal on the indicating switch, through the voltage coil of the battery cut-out, and thence to the terminal $+A$ on the switch, where it divides, one side leading to $+A$ on the battery and through the battery to $-A$ on the starting switch. The other half of the current flows through a jumper in the switch to $+B$ on the starting switch, through to the same terminal on the battery, and through the battery to $-B$ on the starting switch. It will be noted that

the common return points of the current at the starting switch are $-B$ and $-D$, and from there the current flows to $-D$ on the generator.

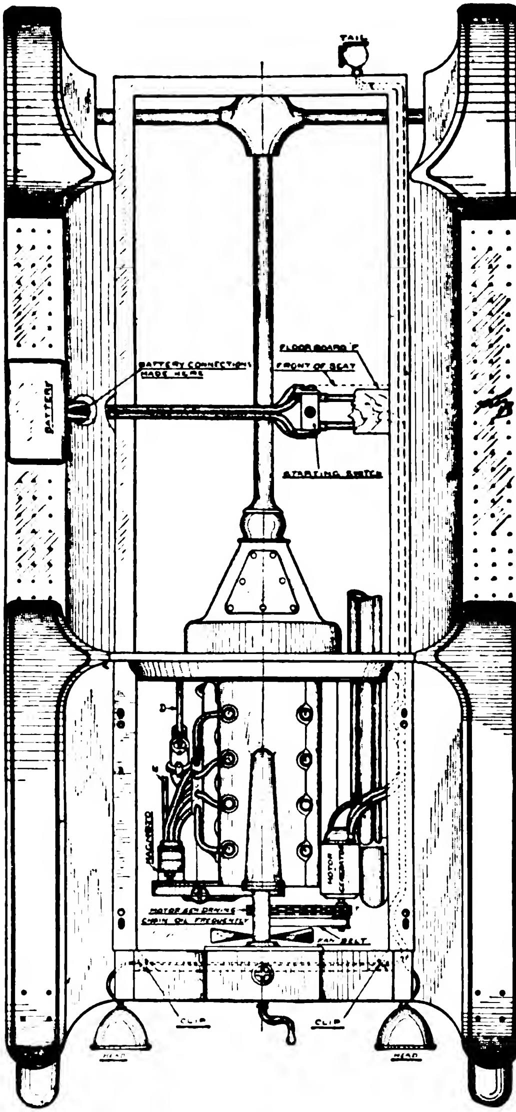


Fig. 419. Plan of Ford Chassis, Showing Installation of Splitdorf Starting Switch

Starting Switch. When the starting switch is closed by depressing its foot button, the current flows from $+A$ at the battery to $+A$

on the starting switch, through the switch to $+M$ on the switch, and thence to the terminal $+M$ on the motor, through the latter to $-B$ $-D$ on the starting switch, and then to $-B$ on the battery, through the battery to the $+B$ terminal, and thence to the $+B$ terminal on the starting switch, through the switch to $-A$ on the switch, and thence to the $-A$ terminal on the battery, and through the battery to $+A$, completing the circuit.

Instructions. *Generator-Motor.* See that the unit is lined up accurately so that the chain runs perfectly true. If this is not done, the chain will be noisy and will wear abnormally on one side and eventually break. A poorly aligned chain will also wear the sprockets. Watch the chain carefully during the first hundred miles or so of running and, as often as required, take up any slack that appears until the chain seats itself. The life of the chain will be greatly prolonged by keeping it well lubricated and at the proper tension. If for any reason it becomes necessary to remove the battery from the car, the engine must not be run without first connecting terminals $-D$ and $+D$ of the dynamo with a piece of copper wire.

The commutator should be kept clean by wiping at regular intervals with a clean rag; if it becomes blackened, note whether there is undue sparking between the brushes and the commutator and, if necessary, sand-in the brushes to correct this. Use No. 00 sandpaper for this and also for brightening up the face of the commutator itself. After this operation, remove all traces of carbon, sand, and metallic dust from the commutator housing as well as from the spaces between the commutator segments. Do not change the position of the brushes or alter the tension of the brush springs unless they have weakened after one or more years of running. See that the brush leads do not rub against the armature, as this will chafe the insulation off and cause a ground or a short-circuit. The generator-motor should be oiled about every thousand miles, using five to six drops of good light oil in each oil hole. See that the fan belt is running true on the pulleys, otherwise it will ride the flange of the pulley and either fly off or break.

Starting Switch. If the brushes of the switch wear unduly, see that the foot button of the switch is not sticking in the floor board. The hole through which the rod of the button operates should be large enough to prevent the pedal spring from rubbing against the

floor board. The switch sticking down will cause both its own brushes and those of the generator-motor to burn and wear badly. See that when the starting-switch pedal returns to its normal position proper contact is made. This can be determined by removing the cover of the switch.

Indicating Automatic Switch. When the engine is running very slowly, the dial may indicate ON and OFF in rapid succession, fluttering continually. This is caused by the engine running at, or very close to, the speed at which the battery cut-out is designed to operate, so that no attention need be paid to it. Should this fluttering occur at medium or at high speeds, it indicates a loose connection in the wiring, either on the generator line, on the back of the cut-out, or in the starting switch. This, if neglected, will cause the contact points of the battery cut-out to burn badly, so that all connections should be gone over regularly to see that they are kept tight. As the generator output is controlled by means of a reversed compound field winding, or bucking coil, there is no regulating device combined with the battery cut-out. The battery has six cells, all of which are connected in series for starting, giving current at 12 volts. For both charging and lighting, the cells are coupled in two units of three each in series-multiple, so that 7-volt lamps are used. They are protected by a fuse on the back of the battery cut-out.

WESTINGHOUSE

Preparing Engine. Adjust the ignition and the carburetor so that the engine fires evenly and regularly before beginning the installation. Remove the radiator and water connections, three forward left-cylinder head bolts, and the fan and bracket timer. Turn the engine shaft until the pin in the fan pulley is in a perpendicular position *h*, and then remove the starting crank and the fan pulley, Fig. 420. Use a bulldozing tool to expand the front end of the engine oil pan, Figs. 421 and 422. (This tool is obtainable from the Westinghouse Company.) It is very important that at least $\frac{3}{8}$-inch clearance beyond the sprocket be obtained, as shown in Fig. 433. Be sure to use the bulldozing tool with the spacing hub *XI*, Figs. 421 and 422, always next to the engine case. The tool is made in two parts and is reversible so as to be available for right-hand and left-hand operations.

Mounting Starter. The crankshaft sprocket *H* is assembled by the manufacturer and adjusted to the correct tension. Dismantle the

Fig. 420. Ford Engine Ready for Installation of Westinghouse Electric Equipment

sprocket. See that the pin hole in the crankshaft is in a vertical position *h*, Fig. 420, and then drive the new sprocket hub *H*, Fig. 423, in place so that the hole in the sprocket is in line with the hole in the

Fig. 421. Use of Bulldozing Tool on Westinghouse Ford System

Fig. 422. Using Hammer to Help Bulldozing Tool

crankshaft. The sprocket hub must be a tight fit on the crankshaft and should be driven into place by means of copper or brass bar, as

shown at *b*, Fig. 423. Drive the pin *H-1*, Fig. 424, through the sprocket hub *H* and the shaft, and be sure that the head end is flush with the surface of the hub. If the pin *H-1* is not a tight fit in the

Fig. 423. Putting on Crankshaft Sprocket Hub in Westinghouse System

shaft, it should be bent slightly at the center to make it tight. Use a drift for driving pin *H-1* into place so as not to injure the pin or the

Fig. 424. Inserting Sprocket Pin with Drift

hub. To be sure that the pin *H-1* in not projecting too far at the extended end, place the sprocket *H-4*, Fig. 425, on the hub and turn it several revolutions. If it does not turn freely, the pin *H-1*,

Fig. 424, probably strikes the inside of the sprocket, and therefore the pin should be trimmed until it just clears.

Remove the sprocket *H-4* and place one of the friction collars *H-5* on the hub. Now spring the spring ring *H-2*, Fig. 425, into place on the hub *H*, so that the small hole in the ring engages with the projecting end of the small pin. It will not go into place any other way. *Be sure that the free end of the spring ring projects at least $\frac{5}{16}$ inch out from the surface of the sprocket hub*, Fig. 425. Place the chain *I* under the sprocket hub. Slide the sprocket *H-4* over the spring ring. Pack the sprocket with good cup grease and place the other friction washer *H-5* on the forward side of the sprocket. Now place the stationary washer *H-6* over the keyway in the sprocket hub and put the spring washer *H-7* on the outside of this and fasten it in place with the nut *H-8*, as shown in Fig. 425. The nut *H-8* should be tightened until the mark "O" on the nut corresponds with the mark in the keyway *a* on the hub, Fig. 426. The grooves in the face of the nut should register with the flukes of the spring washer.

Fig. 425. Assembly of Westinghouse Crankshaft Sprocket

Remove the nut from the forward left-hand bearing bolt and replace it with a special flat Westinghouse nut *G-1*, as shown in Fig. 420. Place the lock washer *G-2* on top of this nut and screw the cylindrical nut *G* down tight with the lock washer. Replace the Ford timer. Set the Westinghouse electric unit *A*, Fig. 427, in place on the engine, using in the cylinder head the three special screws *D* (furnished for this purpose) and the special cylindrical nut *G* (provided). Adjust the center distance between the engine crankshaft and the electric-unit shaft, as shown in Fig. 427. The distance should be $11\frac{25}{32}$ inches, as shown, and *all three points of support* should touch.

Fig. 426. Detail of Sprocket Showing Adjustment

Remove the sprocket *B* from the electric unit shaft, Fig. 428. Insert the sprocket in the endless driving chain *I* and press the

Fig. 427. Adjusting Distance between Centers of Crankshaft and Motor Shaft

sprocket on the shaft, as shown. When the sprocket is in place, there should be *at least 10 pounds tension on the chain.* If the tension is

Fig. 428. Putting on Shaft Sprocket and Chain

less than 10 pounds, adjust the center distance as directed until the required tension is obtained. A new silent chain is elastic to some

extent, and, for this reason, a new chain is adjusted to run under the tension mentioned. After running about 2000 miles, the chain may be loose enough to strike the chain guard. This is a warning to tighten

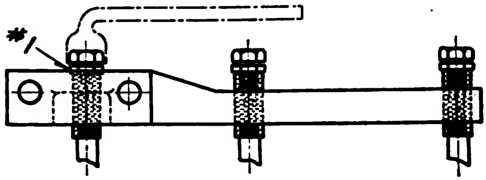


Fig. 429. Diagram Showing Chain Adjusting Bolts

the chain. To do this, loosen the three bolts, Fig. 429, about one full turn from the top supporting bracket. Tighten the adjusting bushings nearest the radiator until the tension is correct. Set the other bushings to agree and tighten all the support bolts. *Do not run*

Fig. 430. Tightening Mounting Bracket with Shaft Pulley in Plates
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

the chain under tension after the first adjustment. This is very important. If the chain is too tight, it will produce a grinding noise. When properly adjusted, the chain should be so loose that when pressed on with the finger it will give about $\frac{1}{2}$ inch.

After replacing the fan pulley *B-1* and tightening the nut *B-2*, be sure to replace the cotter pin *B-3*, Fig. 430. Mount the chain guard

Fig. 431. View of Westinghouse Installation, Showing Chain Guard and Part of Wiring Arrangement

Fig. 432. Fan in Place and Headlights Mounted

L on the unit and see that it lines up, as shown in Fig. 431. Clamp the split fan pulley *J* on the Ford fan pulley, as shown in Figs. 428 and 430, and replace the fan on the engine, using the new fan belt *K*,

Fig. 433. End and Side Elevations of Westinghouse Ford Installation, Showing Correct Position of Parts on Engine

Fig. 432. Bend the fan blade slightly to clear the electric unit. Instead of the Ford cranking claw and pin, use the Westinghouse sleeve *H-9* and pin *H-10*, respectively, Fig. 433. When the Ford starting crank is replaced, it may be found slightly out of alignment. Insert a bar in the starting-crank bearing and spring the bearing into alignment. This completes the installation of the unit itself.

Fig. 434. Diagram Showing Mounting of Starting Switch and Cut-Out

Lighting and Starting Switches. Mount the two-gang lighting switch *P* on the right-hand side of the dash. Cut a rectangular hole in the dash at a point low enough so that the carburetor adjusting rod will not touch the contact screws of the switch when it is fastened in place by means of four wood screws to the cover plate on the face of the dash. Mount the fuse *Q* just below the lamp switch on the engine side of the dash, as shown in Fig. 431. Note that on 1915 Ford cars the new cowl dash may make it necessary to change the location of the speedometer slightly in order to provide space for the lamp switch.

The starting switch and generator cut-out *O*, Fig. 434, should be located on the heel board at the left-hand side of the car, approximately 2 inches from the car frame. The terminals should be toward the right side of the car. Mount the battery box on the right running board, as shown in Fig. 435, and drill two $\frac{3}{4}$-inch holes in the mud shield to match the holes in the battery box, Fig. 436, and fasten down with the holding-down bolts.

Fig. 435. Method of Mounting Battery Box on Right Running Board in Westinghouse System

Wiring. The wiring should now be fastened in place, as shown in Figs. 437 and 438. If Westinghouse lamps are used, the dimmer should be removed. Except where wood screws may be used to

attach holding cleats to wood parts, all the holding cleats should be fastened under the bolts already on the Ford chassis. *Be very careful that the cable terminals do not touch any part other than the studs to which they should be fastened.* Carelessness in this particular will result in burned-out apparatus and may actually ruin the battery before the car is ever run. It is equally essential to prevent the metal armor on the cables from touching any of the connecting studs or the terminals. The ground wire should be fastened at one end under one of the supporting bolts of the starting switch and cut-out and at the other end by fastening the connection together with a cleat under the bolt holding the brake and clutch rod to the frame. *Do not connect the ground wire from the battery until all the other wires are in place and fastened.* The ground connection of *W* is made by fastening the connection under a bolt of the muffler support

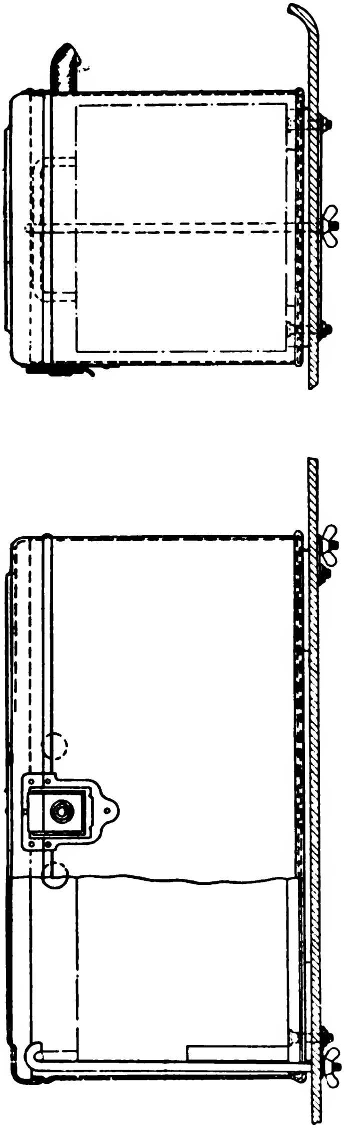


Fig. 436. Side and End Views of Battery Box Mounted on Running Board
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

Attach the lamp connections to the wires. These are of the solderless type which are connected by removing the connector from the lamp, Fig. 439. Slip the casing *a* back over the cable and push the wires through the collar *b*. Strip the insulation from the wire about $\frac{1}{4}$ inch back from the end. With a small screw-driver applied to the sleeve *d*, remove the little metal socket *c* from

Fig. 437. Pictorial Wiring Diagram of Westinghouse Ford System with Other than Westinghouse Ford Lamps

Fig. 438. Pictorial Wiring Diagram for Westinghouse Installation when Westinghouse Ford Lamps Are Used

the connector. Insert the bare ends of the wire in the socket and fasten with small set screws. Replace the socket and fasten it by screwing up on the sleeve *d*. Be sure that none of the strands of the wire project outside of the insulation piece *e*. Attach the head and tail lamps, insert the connecting plugs, and try all circuits to determine if everything is operating satisfactorily.

When Westinghouse Ford electric head lamps are used, Fig. 438, connect them as shown in the diagram, grounding one wire from each lamp, also one wire from the tail-light socket. One switch button will give a dim light and the other switch will give a bright light. If other than the above lamps are used, such as the double-bulb two-wire type headlights, one wire from each lamp socket must be grounded to the lamp housing or the car frame, and the dimmer should be disconnected. If side lights are used instead of double-bulb headlights, with two-wire (double contact) lamps, both wires in cables *W-7* and *W-8* can be used for the headlights, as shown in the diagram for the Westinghouse Ford lamps. The dash end of one wire in each cable must be grounded instead of connecting it to the switch. An additional wire from the switch should be run to one terminal in each side light, and the other lamp terminal should be grounded. The dimmer should then be disconnected.

Fig. 439. Details of Westinghouse Lamp Connector

If side lights are used instead of double-bulb headlights with single-wire lamps, both ends of one wire in the cables *W-7* and *W-8* are useless and should be taped up. An additional wire from the switch should be run to each side light.

Westinghouse Ignition. *Assembly.* If the Westinghouse ignition system is also to be installed, it should be assembled in place at this time, i.e., before replacing the Ford timer housing, the radiator, and other parts, which have been removed to install the electric starting and lighting unit. Remove the timer, or spark advance, rod; the steel bush; the Ford roller contact; the coil box; and all ignition wiring. Place the Westinghouse gear *Z-1*, Fig. 432, on the camshaft in place of the Ford timer roller contact, and fasten it in place with the same pin, cap, and nut used to hold the roller contact. Take out the spark plug of the first cylinder. Turn the engine over until

the piston of cylinder No. 1 is exactly at the upper dead center on the firing stroke, that is, when the piston is at the top of the cylinder *with both valves closed*. The position of the valves and the piston may be seen through the spark-plug hole. Mount the ignition unit in the

Fig. 440. First Step in Installing Westinghouse Ignition

Fig. 441. View of Ignition Installation, Showing Timing Position

supporting bracket and put the holding screw in place. Be sure that the ignition unit turns freely in the bracket. Remove the distributor block and slide the ring cover up. Turn the entire unit until it is in the position shown in Fig. 441. Hold the unit firmly in this position

Fig. 442. Arrangement of Westinghouse Ignition Wiring

and turn the distributor brush arm counter-clockwise (to the left) until the contact brush is in the position shown in Fig. 441 and the interrupter contacts are just beginning to open. Clamp the unit in place on the engine exactly in this position. Use the two special screws *Z-4* to hold the bracket in place on the engine.

Connect the timer rod *Z-5*, furnished with the equipment, to the ignition unit, as shown in Fig. 442. Operate the spark lever on the steering post and see that the Westinghouse ignition unit follows the movement of the control lever. Mount the cover plate on the dash over the holes left by the Ford coil unit and cut a rectangular hole in the dash to receive the Westinghouse ignition switch. Fasten the cover plate and the ignition switch to the dash with the screws furnished for the purpose. Put the distributor block in place on the ignition unit and connect the wires to the spark plugs, as shown in Fig. 442. Be sure to connect each plug to the point shown in the diagram. Connect one end of the small wire *Z-7* to the terminal at the side and near the bottom of the ignition unit that has no other connection and connect the other end to the terminal on the ignition switch.

There are terminals provided for the purpose of reversing the current through the interrupter contacts; changing the short connection from one side to the other side and changing the primary wire reverses the current direction. Connect the terminal *B* on the switch to the negative side of the battery. This connection can be made most easily by using the terminal *B-1* on the starting switch, as shown in Figs. 437 and 438. The positive side of the battery is grounded. The engine may now be started in the usual way.

Operating Instructions. The Westinghouse-Ford system is a 12-volt single-unit single-wire type, the complete unit being permanently connected to the enginge by the silent-chain drive. The driving sprocket has a cushioned positive drive in the starting direction and a friction drive in the generating direction. This friction is adjustable for wear without removing any part of the equipment, as described later under Failure of Generator.

A battery cut-out, or magnetic switch, in the generator circuit serves to protect the battery; it cuts in when the engine attains a speed approximately equivalent to nine miles an hour on the direct drive. On low, it will naturally operate at a very much lower car speed as the engine is then running very much faster. If no lights are on, the battery begins to charge as soon as the cut-out operates; with lights burning, part of the current is diverted to them, but, at fifteen miles an hour or over, sufficient current is furnished to light all the lamps and charge the battery. The details of the cut-out, also of the starting switch, are shown in Fig. 443, while the method of

reassembling the carburetor choker, strangler, or priming device, as it is variously termed, with the new equipment provided, is shown in Fig. 444. In case the engine fails to start after the starting motor has operated five to ten seconds, the ring on the dash should be pulled as far as it will go and held there for a few seconds while the starting motor is operated again. Do not hold the ring down too long; if the

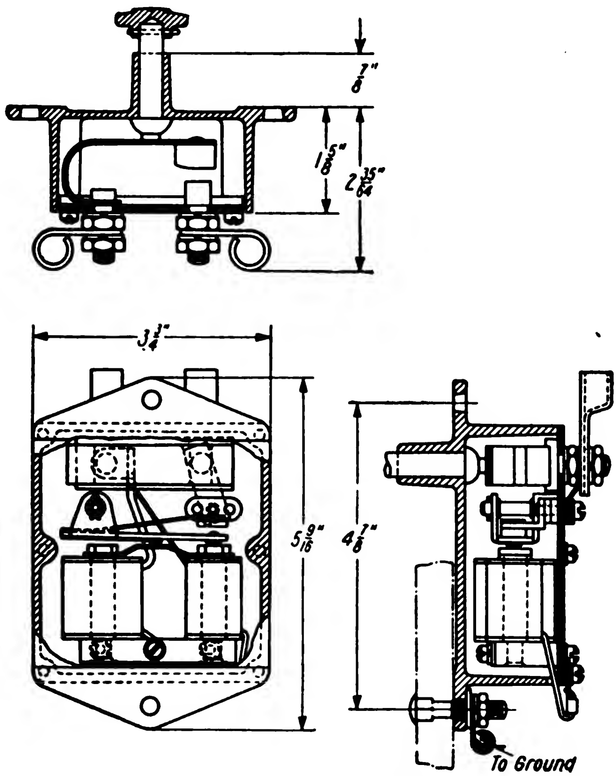


Fig. 443. Construction of Westinghouse Starting Switch and Cut-Out

engine does not start promptly with the carburetor choked, the failure must be caused by something else, and continuous running with the carburetor air inlet closed will quickly flood the engine with liquid gasoline.

Starting Troubles. If the electric motor fails to start when the switch is closed, open the switch and test out as follows, using a direct-current voltmeter: Connect voltmeter to give a reading of over 12

volts and test the battery. If the reading with the lamps on is 11 volts or less, the battery is practically exhausted. Instructions for keeping the battery in good condition will be found under its appropriate heading in the section on Storage Batteries. Trouble of this nature, particularly in cold weather, is frequently caused by not driving the car long enough between stops, so that the generator has no opportunity to charge the battery. Look for an open circuit, i.e., broken wire or loose terminal, in the wires *W*, *W-1*, and *W-2*, Figs. 437 and 438. Remove the spring collar over the brushes and see that they are in good condition, not sticky or gummed with oil and dirt, and are making good contact over their entire bearing surface on the commutator.

To Remove Brushes. Lift the spring that holds the brush in the guide and take out the screw holding the brush shunt, when the brush can be slipped out. In removing each brush, it should be noted which side was turned up, and each brush should be replaced in its original holder in the same way. In putting in new brushes, care should be taken to see that they have a good bearing fit over their entire surface on the commutator. To obtain this, they must be sanded-in (see Delco instructions). Only brushes supplied by the manufacturers of the system should ever be employed.

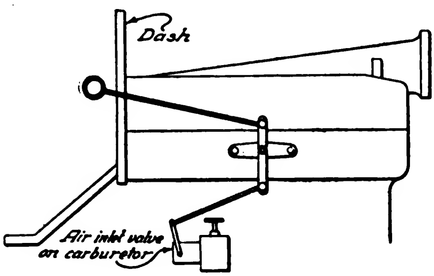


Fig. 444. Layout of Carburetor Strangler

Battery Does Not Stay Charged. If the car is not run for a sufficient length of time during the day or at a speed high enough to charge the battery, there may a ground in the wiring. With the engine idle and the lights off, disconnect the battery wire and touch it lightly on the terminal a few times. If a spark occurs, there is a ground in the wiring. The battery may not charge even at high speeds, owing to different causes. If there is a loose connection between the starting switch and the electric unit, see that the terminals hold the wire *W-2* tight and examine the wire between the terminals for breaks. The cut-out may not be operating properly. With the engine running, vary the speed and watch the contacts of the cut-out

to see that they connect the battery in the circuit at a speed above nine miles an hour and break the circuit again when the speed drops below this point. The cut-out contacts should be separated when the engine is not running, and they should remain closed as long as the engine runs above a certain speed. This cutting-in speed varies slightly. If the contacts do not close, there may be oil on the brushes or on the commutator; or one of the brushes may be worn too short; or one of the brush springs may be too loose.

Loose Friction Drive. If the commutator, the brushes, all the connections, and the wiring are in good condition, the trouble may be caused by the generator drive. To find out whether the friction sprocket has lost its tension or not, try to turn the electric unit by hand in both directions with the engine stationary. If it can be turned by hand easily in one direction, the nut *H-8* should be tightened sufficiently to enable the engine to drive the electric unit, Fig. 425. When running at 15 to 20 miles an hour, a faint click may be heard about every five minutes. If the clicking is more rapid than three or four times every five minutes, tighten the adjusting nut one-third to one-half turn.

The shunt-field brush *a* may not touch the commutator, Figs. 437 and 438. Adjust this brush, sanding it in, if necessary, and if this does not correct the trouble, test out the shunt-field circuit for open connections. This includes all circuits through the starting switch and the shunt-field winding. If the shunt-field winding is found to be open-circuited, the trouble was, no doubt, caused by an open circuit between the generator and the battery or by running the generator disconnected from the battery.

Lamps Do Not Light. If confined to a single lamp, this may be owing to the bulb having burned out, to an open circuit, or to a broken connection in the wiring. Should replacing with a new bulb not correct the trouble, test all the connections and the wiring and see that the lamp socket is grounded. When none of the lamps will light, test for a voltmeter reading with the lamps turned on but with the engine idle. If the voltmeter shows no reading, this may be owing to a broken connection at the battery or to the terminals having become so corroded as to amount to the same thing. The wire *W* may be disconnected or broken. If the voltmeter reading is correct, the trouble may be caused by a blown fuse. Should this be the case, do

not replace it immediately, but look over the wiring and the connections for an accidental ground or a short-circuit. In looking for grounds, hunt for abrasions of the insulation on the wire or for mechanical contacts between the ends of the cables or current-carrying parts of the wiring devices and the metal of the car, the socket, the shells, etc. When the trouble has been located and corrected, replace the blown fuse with another of the same type and capacity. If the trouble cannot be located immediately, turn off the switch on the damaged circuit and do not use until it can be remedied. Should the trouble be in a particular lamp socket, disconnect the attachment plug from this socket until the difficulty can be remedied and see that the removed attachment does not dangle against the metal of the car in such a way as to cause short-circuits.

All the lamps may be burned out. This is likely to happen when a battery wire breaks or becomes disconnected. It is also not unlikely that the battery may be entirely exhausted, though it will seldom get down to a point where the lamp filaments will not glow at least a dull red, without its condition having been detected. If the lamps become dim as soon as the engine stops, this indicates an exhausted battery, and if not convenient to drive the car to recharge it, the battery should be charged from an outside source. When the lamps flicker or go out momentarily, there is a loose connection, and the fact that all the lamps are thus affected indicates its location at the battery or in the wire *W-1*, Fig. 437. Should but one lamp be affected, only its particular circuit is at fault, and the trouble will usually be found in the socket itself, though a parted ground connection, which, owing to the vibration, will sometimes touch and at other times be shaken away from its contact, may be responsible. As a 6-cell battery is supplied, 14-volt lamps must be used.

Operation of Ignition Unit. The vertical ignition unit of the Westinghouse type is composed of four essential units, viz, the interrupter, or contact-breaker; the induction coil; the distributor; and the condenser. The operation of the interrupter may be observed by lossening the thumb screw *E* and sliding upward the loose section of the insulating housing which forms the interrupter cover, Fig. 445. With the ignition switch "On" and the engine running, each segment of the interrupter cam, in turn, passes on and off the fiber bumper, Fig. 445. As each cam passes off the bumper, the interrupter contacts

close, closing the circuit from the battery to the primary winding of the coil. Then, as they are lifted by the bumper, the contacts are separated, suddenly opening the circuit and inducing a high-tension current in the secondary of the induction coil. This current is directed by the distributor on top of the ignition unit to the proper spark plug. The ignition switch is a simple, single-pole type connecting

Fig. 445. Parts of Westinghouse Ignition Unit

the negative side of the battery to the ignition terminal, Fig. 446. This switch is a reversing type, i.e., it changes the direction in which the current passes through the interrupter contacts each time it is operated. Particular attention is directed to the rear view of the switch. As received, this switch does not operate to reverse the current direction. If it be desired to utilize this feature, remove the

Fig. 446. Front and Back Views of Westinghouse Ignition Switch

metal strip that connects two of the three terminals on the ignition unit. Also remove the metal strip that connects two of the four switch terminals. Connect the terminal on the switch to the center terminal on the ignition unit. Obtain two extra wires, like the one supplied to connect the switch and the ignition unit, and connect the two switch terminals to the two outside terminals on the ignition unit.

Ballast Resistor. This is a resistance unit which will be noted mounted on the rear face of the switch, Fig. 446. It is connected in series with the primary ignition circuit and is an important part of the ignition system, its function being to protect both the ignition system and the battery. In case this resistance unit should become broken or inoperative from any cause, a standard 5-ampere fuse may be used in an emergency, *but a fuse of more than 5-ampere capacity must never be employed in any case.* Unless absolutely necessary to do so in order to run the car, the ignition system should never be operated without the ballast resistor, as serious injury is likely to result. A very fine piece of wire, such as a single strand of lamp cord, should be used for bridging the gap.

ELECTRIC GEAR-SHIFT

General Plan. One of the more recent additions to the electrical equipment of the automobile that the installation of a generator and a constantly charged storage battery on the car has made possible is the electric gear-shift. While it has not yet been extensively adopted, it is already in use on a number of cars and is slowly coming into favor, and from now on the garage man will find more machines thus fitted coming into his hands and will be called upon to give attention to this as well as to the other parts of their electrical equipment.

In the standard three-speed and reverse gear of the selective type, four movements are necessary to engage all the speeds. These changes in the relations of the gears are carried out by means of a sliding pinion for first and second speeds, a toothed clutch for direct drive, and the interposition of an idler between two of the driving gears to give the reverse, all these movements being accomplished by means of a yoke on the member to be moved. This yoke is mounted on a movable rod, or bar, which is, in turn, connected through convenient linkage to the hand lever. In the electrically operated gear, all these parts, with the exception of the hand lever, which is dispensed with, remain the same and their functions are unaltered. The bars on which the yokes are mounted, two in number, Fig. 447, are lengthened somewhat, and their extended ends form armatures, or cores, for four solenoids.

Principle of Action. As has been explained in the introductory in connection with electromagnetism, passing a current through a

solenoid will cause it to draw its core into the coil. This is the principle on which the electric gear-shift operates. There is a solenoid for each movement necessary. For example, to obtain first speed, the bar *A*, which carries the yoke attached to the sliding gear (not shown), must be moved to the left, Fig. 447. To accomplish this, button *1* is pressed. This closes the circuit through the solenoid *1*, but no current flows through its winding until the master switch controlling the current supply to all the solenoids is closed. The master switch is operated by pushing the clutch pedal forward, exactly as when shifting a gear by hand. This energizes solenoid *1*, the bar *A* moves to the left, carrying the sliding pinion with it by means of the usual yoke, and the first-speed gear is engaged. The operation throughout is the same. A neutralizing device, described later, opens the master switch and cuts off the current. The speed desired is selected by pushing the numbered button under the steering wheel, the clutch is disengaged momentarily by pushing the pedal all the way forward when the change is desired, and the gears shift automatically. Thus the solenoid *2* moves the bar *A* to the right to give second, or intermediate, speed; solenoid *3* moves the bar *B* to the left to give the direct drive, or high speed; while *R* moves the same bar to the left to give the reverse engagement.

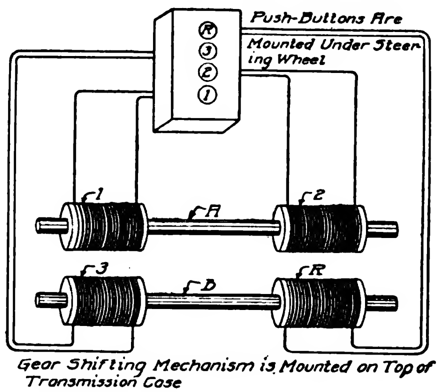


Fig. 447. Diagram Showing Principle of Electric Gear-Shift
Courtesy of Cutler-Hammer Manufacturing Company, Milwaukee, Wisconsin

The buttons on the steering post, when pressed do not entirely close the circuit but merely place the particular solenoid which they control in connection with the master switch. They are known as "selector switches". They select in advance the circuit which will be energized when the master switch is closed. To do this, the clutch pedal must be depressed all the way, in order to permit de-clutching without bringing this switch into action, that is, when the clutch pedal is depressed only part way, as in cutting off the power, no contact is made at the master switch.

Stopping the Car. When it is desired to stop the car, the clutch pedal is depressed all the way, after the neutral button has been pressed. Pressing this button breaks any contacts that may have been made previously by the selector switch buttons, and depressing the clutch pedal then brings into action what is termed the neutralizing device. For example, the car has been running on high, the neutral button is pressed and the clutch pedal pushed all the way forward. This causes the operating lever *K* to move ahead, Fig. 448. Then the neutralizing cams *F* pull on the boss on the shifter forks as if a shift were to be made, and the master switch *M* will also close; but, as the neutral button has opened all the selector switches,

Fig. 448. End View of C-H Neutralizing Mechanism and Master Switch
Courtesy of Cuttler-Hammer Manufacturing Company, Milwaukee, Wisconsin

no current flows, and as the solenoids are not energized, the gears remain in neutral. Fig. 449 shows a plan view of the neutralizing mechanism and the master switch, while Fig. 450 illustrates the solenoids (two of them) and their mounting in detail. The relative locations of these solenoids to the remainder of the operating mechanism is shown by the phantom view of the complete gear box, Fig. 451. The solenoids are identified by the letters *B1*, *2*, etc., and their cores by the letters *C1*, *2*, etc. A complete wiring diagram is given in Fig. 452.

Starting First Speed. Assuming that the gears are in neutral and it is desired to start, then first-speed button of the selector switch on the steering wheel is pressed, partly closing the circuit of one of

the magnets. Depressing the clutch pedal all the way rotates the lever *K* through the connecting rod *L* which is linked to the clutch

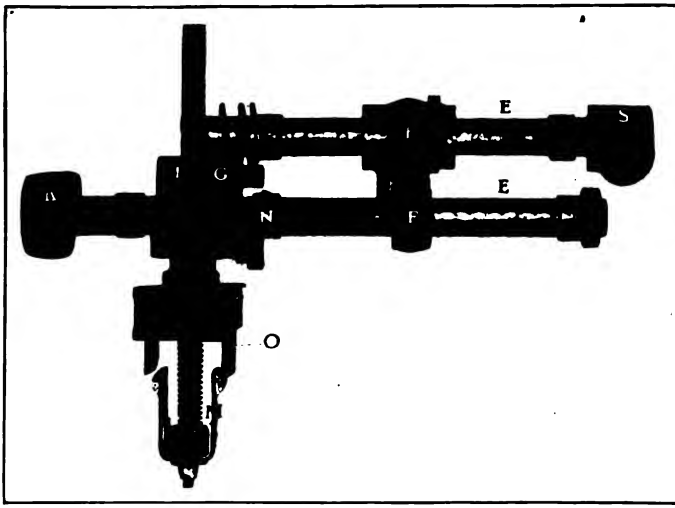


Fig. 449. Plan View of C-H Neutralizing Mechanism and Master Switch
Courtesy of Cutler-Hammer Manufacturing Company, Milwaukee, Wisconsin

pedal. This pulls the blades of the master switch *M* into contact, completing the circuit and energizing the solenoid. As the gears engage,

Fig. 450. View of Magnet Case and Electric Solenoids
Courtesy of Cutler-Hammer Manufacturing Company, Milwaukee, Wisconsin

and the sliding member is within ½ inch of being "home", the pawl *G*, Fig. 448, falls back, owing to the pull of the magnet against the

neutralizing cams F, causing it to strike against the trigger N, which is attached to the switch-operating pawl L. This action causes the pawl L to be raised out of engagement with the stem of the master

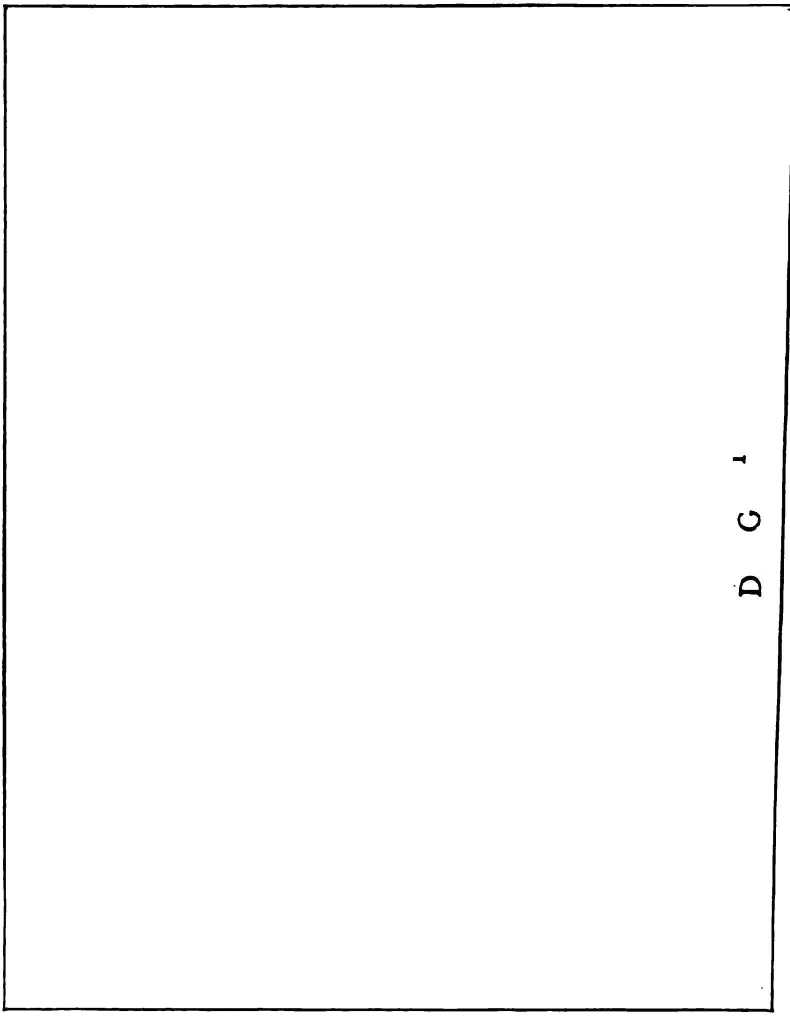


Fig. 451. Phantom View of C-H Gear-Shifting Arrangement

switch, and the latter snaps open instantly, owing to the pull of the spring O, Fig. 449. The actual time of engagement, during which current is being drawn from the battery, is said to be less than one-third of a second.

From First to Intermediate or High. Being in first speed and desiring to shift, the button corresponding to the speed desired, i.e., either intermediate or high, is pressed at the convenience of the driver. When it is desired to make the change, the clutch pedal is pushed all the way forward, this action rotating the operating lever

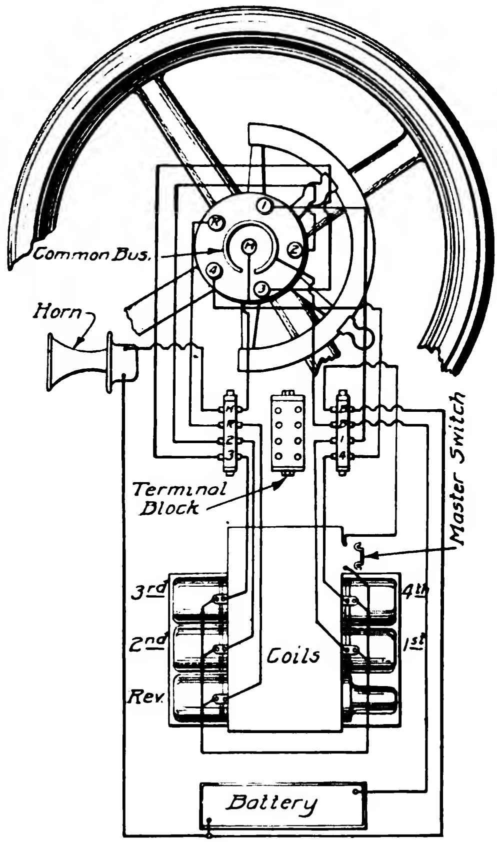


Fig. 452. Complete Wiring Diagram for C-H Electric Gear-Shift

K and its shaft which carries the rocker arm *I* and its attached mechanism. As the first gear, or whichever gear has been previously operated, is still in mesh, the latch *H* is in engagement with the pawl *G* of the neutralizing mechanism, and, as the operating lever and the rocker arm *I* are rotated, the latch *H* presses against the pawl *G*, causing both of the neutralizing cams *F* to rotate toward the center,

owing to their being engaged through the teeth *P*. On the central side of the shifter forks *D*, Fig. 451, there is a boss, and as the neutralizing cams *F* rotate, they press against the boss on whichever side is in engagement. This mechanically pulls the shifter fork and the gear with which it is engaged back to the neutral position before the next shift can be made. As the gear reaches the neutral position, the end of the latch *H* strikes the knockout pin. This action releases the latch from engagement with the pawl *G*, and as the operating lever *K* is moved ahead by the driver's foot on the clutch pedal, the switch operating pawl *L* pulls against the switch stem, closing the circuit at the master switch. This action is the same for all speeds in the gear box. In case of failure of the current through exhaustion of the battery or other cause, an emergency hand lever may be inserted in the socket *S* and the gears may be changed in the usual manner by hand.

Wiring. Referring to the wiring diagram, Fig. 452, it will be noted that the wiring is very simple. To permit the removal of the gear box, if necessary, without having to disconnect any permanently fastened cables, all the wires are led to a terminal block, the actual location of which is shown on the gear box, Fig. 451. Connections at this terminal block are simplified by making each terminal a different size so that the wires can be replaced only on the terminals which correspond to them. There is, accordingly, no risk of confusing them. A single wire leads from each magnet coil through the terminal block to its particular speed button on the selector switch, while the other lead from the coil is connected to a neutral wire directly through the terminal block and the master switch to the battery. Another wire from the battery passes through the terminal block to the contact of the selector switch which is common to all speeds. The circuit is accordingly from the positive terminal of the battery through the depressed push button on the selector switch, through the winding of the coil to which the button in question corresponds, and back through the master switch to the other terminal of the battery.

Operating Troubles. A failure on the part of the gear box to shift electrically would be likely to occur, after considerable usage, in about the following order:

(1) A break in the linkage connecting *L* with the clutch pedal, which would prevent the neutralizing mechanism from coming into operation, and would also prevent the master switch from closing.

(2) Dirt or wear which would prevent the fingers of the master switch from making proper contact; failure of the spring *O*, of the master switch, through breakage, so that the master switch would not open automatically immediately upon completing the shifting of the gears, as is normally the case.

(3) Excessive jolting and vibration causing some of the leads to shake loose from the terminal block.

(4) Breakage or loosening of some of the connections at the selector switch owing to the same cause. (The wiring itself is so well protected that any injury to it is remote.)

(5) Jamming of the solenoid cores in the brass tubes in which they slide in the coils, owing to the shaft getting out of alignment. To operate properly, it should be easy to move the entire shifting mechanism by hand with very little effort.

(6) Exhausted storage battery which, as a matter of fact, should always be tested first, but which, like the empty gasoline tank, is such patent cause of failure that it seems almost unnecessary to mention it, either first or last. As is pointed out at considerable length under the appropriate heading, there are numerous causes for the exhaustion of the battery, so that its condition should always be inspected before attempting to investigate the shifting mechanism.

Should an examination prove the battery to be sufficiently charged, the electric test-lamp set—described in connection with trouble hunting in the starting and lighting systems—will prove a valuable aid in running down the open circuit or the short-circuit that is preventing the gear box from operating. Test the circuit of each solenoid in turn; inspect the connections of the master switch and the condition of its contact fingers, also the connections at the terminal block and at the selector switch. The test lamp should quickly reveal just which circuit is at fault.

WESTINGHOUSE STARTING AND LIGHTING SYSTEM AS DESIGNED FOR H.A.L. TWELVES

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART VIII

ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

STARTING AND LIGHTING STORAGE BATTERIES

Importance of the Battery in Starting and Lighting. In the last analysis, every electric lighting and starting system on the automobile is necessarily a battery system. An electric starter is, first and last, a battery starter, since no system can be any more powerful than its source of energy. In other words, the storage battery is the business end of every electrical starting and lighting system. Just as the most elaborate and reliable ignition apparatus is of doubtful value with poor spark plugs, so the finest generators, motors, and auxiliaries become useless if the battery is not in proper working order.

Storage Battery Requires Careful Attention. A little experience in the maintenance of electric starting and lighting systems will demonstrate very forcibly that the relative importance of the storage battery is totally disproportionate to that of all the remaining elements of the system put together. The latter essentials have been perfected to a point where they will operate efficiently without attention for long periods. The battery, on the other hand, requires a certain amount of attention at regular and comparatively short intervals. Usually, this attention is not forthcoming, or it may be applied at irregular intervals and with but scant knowledge of the underlying reasons that make it necessary. Consequently, the battery suffers. It is abused more than any other single part of the entire system and, not being so constituted that it can withstand the effects of this abuse and still operate efficiently, it suffers correspondingly. Then the entire system is condemned.

Other things being equal, the successful operation of any starting and lighting system centers almost wholly in the proper maintenance of the storage battery. Not all the defections that this part of the electrical equipment of the car suffers are caused by the battery, but unless properly cared for, it will be responsible for such a large proportion that the shortcomings of the rest of the system will be entirely forgotten. To make it even stronger, it may well be said that unless the storage battery is kept in good condition, the rest of the system will not have an opportunity to run long enough to suffer from wear. In a great many cases that come to the repair man's attention, the battery is ruined in the first six months' service, usually through neglect. For this reason, considerable attention is devoted to the battery and its care in this connection, despite the fact that it is very fully covered in the volume on Electric Vehicles. The conditions of operation, however, are totally unlike in the two cases. In one instance, the energy of the battery is called for only at a rate of discharge which is moderate by comparison with the ampere-hour capacity, while the battery itself is constantly under the care of a skilled attendant. In the other instance, the demand for current is not alone excessive but wholly disproportionate to the total capacity of the battery when it is used for starting, and intelligent care is usually conspicuous by its absence.

PRINCIPLES AND CONSTRUCTION

Function of Storage Battery. In the sense in which it is commonly understood, a battery does not actually store a charge of electricity. The process is entirely one of chemical action and reaction. A battery is divided into units termed *cells*. Each cell is complete in itself and is uniform with every other cell in the battery, and one of the chief objects of the care outlined subsequently is to maintain this uniformity. Each cell consists of certain elements which, when a current of electricity of a given value is sent through them in one direction for a certain length of time, will produce a current of electricity in the opposite direction if the terminals of the battery are connected to a motor, lamps, or other resistance. The cell will, of course, also produce a current if its terminals are simply brought together without any outside resistance. This, however, would represent a *dead short-circuit* and would permit the battery to dis-

charge itself so rapidly as to ruin its elements. This is one of the things that must be carefully guarded against. When attending a battery, see that its terminals are not left exposed where tools may accidentally drop on them. When the current is being sent into the battery, as mentioned above, it is said to be charging; when it is connected to an outside resistance, it is discharging.

Parts of Cell. *Elements.* These are known as the positive and negative plates and correspond to the positive and negative electrodes of a primary battery. They consist of a foundation composed of a casting of metallic lead in the form of a grid, the outer edges and the connecting lug being of solid lead, while the remainder of the grid is like two sections of lattice work so placed that the openings do not correspond. Every manufacturer has different patterns of grids, but this description will apply equally well to all of them. Fig. 453 illustrates the grid of the Philadelphia battery. The object in giving them this form is to make the active material of the plates most accessible to the electrolyte, or solution, of the battery, and at the same time to insure retaining this active material between the sides of the grid.

Fig. 453. Lead Grid Ready for Active Material
Courtesy of Philadelphia Storage Battery Company, Philadelphia, Pennsylvania

This active material consists of peroxide of lead (red lead) in the positive plate and litharge, or spongy metallic lead, in the negative plate. The plates are said to be pasted, to distinguish them from the old-style plates which were "formed" by a number of charges and discharges. The active material is forced into the interstices of the grid under heavy pressure, so that when completed the plate is as hard and smooth as a piece of planed oak plank. The positive plate may be distinguished by its reddish color, while the negative is a dark gray. Each positive plate faces a negative in the cell, and as the capacity of the cell is determined by the area

of the positive plates, there is always one more negative plate than positive plates in a cell. The lead connectors of each of the plates is burned to its neighbor of the same kind, thus forming the positive and negative groups which constitute the elements of the cell.

Separators. As the elements must not be allowed to come in contact with each other in the cell because to do so would cause an internal short-circuit to which reference is made later, and as the maximum capacity must be obtained in the minimum space, the plates are placed very close together with wood and perforated hard rubber separators between them. These are designed to fit very snugly, so that the combined group of positive and negative plates is a very compact unit. When reassembling a cell, it is important that these separators be properly cared for in accordance with the directions given later.

Electrolyte. To complete the cell, the grouped elements with their separators are immersed in a jar holding the electrolyte. This is a solution consisting of water and sulphuric acid in certain proportions, both the acid and the water being chemically pure to a certain standard. This is the grade of acid sold by manufacturers as battery acid and in drug stores as C.P. (chemically pure), while the water should be either distilled, be cleanly caught rain water, or melted artificial ice. In this connection, the expression "chemically pure" acid is sometimes erroneously used simply to indicate acid of full strength, i. e., undiluted, as used in the cells in the form of electrolyte. It will be apparent that whether at its original strength or diluted with distilled water, it is still chemically pure. In mixing electrolyte, a glass, porcelain, or earthenware vessel must be used and *the acid must always be poured into the water.* Never attempt to pour the water into the acid, but always add the acid, a little at a time, to the water. The addition of the acid to the water does not make simply a mechanical mixture of the two but creates a solution in the formation of which a considerable amount of heat is liberated. Consequently, if the acid be poured into the water too fast, the containing vessel may be broken by the heat. For the same reason, if the water be poured into the acid, the chemical reaction will be very violent, and the acid itself will be spattered about. Sulphuric acid is highly corrosive; it will cause painful burns whenever it comes in contact (even in dilute solution) with the skin and will

quickly destroy any fabric or metal on which it falls. It will also attack wood, for which reason nothing but glass, earthenware, or hard rubber containers should be employed.

Specific Gravity. The weight of a liquid as compared with distilled water is known as its specific gravity. Distilled water at 60° F. is 1, or unity. Liquids heavier than distilled water have a specific gravity greater than unity; lighter liquids, such as gasoline, have a specific gravity less than that of distilled water. Concentrated sulphuric acid (battery acid, as received from the manufacturer) is a heavy oily liquid having a specific gravity of about 1.835. A battery will not operate properly on acid of full strength, and it is therefore diluted with sufficient water to bring it down to 1.275. This, however, is the specific gravity of the electrolyte only when the battery is fully charged. The specific gravity of the electrolyte affords the most certain indication of the condition of the battery at any time, and its importance in this connection is outlined at considerable length under the head of Hydrometer Tests. The following table shows the parts of water by volume, the parts of water by weight, and the percentage of acid to water to produce electrolyte of different specific gravities.

Action of Cell on Charge. When the elements described are immersed in a jar of electrolyte of the proper specific gravity, and terminals are provided for connecting to the outside circuit, the cell is complete. As the lead-plate storage battery produces current at a potential of but two volts per cell, however, a single cell is rarely used. The lowest number of cells in practical use is the three-cell unit of the 6-volt battery used for starting and lighting on the automobile. The different cells of the battery are usually permanently connected together by heavy lead straps, while detachable terminals are provided for connecting the battery to an outside circuit. When the charging current is sent through the cell, the action is as follows: The original storage-battery cell of Planté consisted simply of two plates of lead; when the current was sent through such a cell on charge, peroxide of lead was deposited on the positive plate and spongy metallic lead on the negative. This was termed "forming" the plate. By modern methods of manufacture, this active material is formed into a paste with dilute sulphuric acid, and is pressed into the grids. On being charged, this acid is forced

out of the plates into the electrolyte, thus raising the specific gravity of the electrolyte. When practically all of this acid has been transferred from the active material of the plates to the solution, or electrolyte, the cell is said to be fully charged and should then show a specific gravity reading of 1.275 to 1.300. The foregoing refers of course to the initial charge. After the cell has once been discharged, the active material of both groups of plates has been converted into lead sulphate. The action on charge then consists of driving the acid out of the plates and at the same time reconverting the lead sulphate into peroxide of lead in the positive plates and into spongy metallic lead in the negative plates.

Action of Cell on Discharge. The action of the cell on discharge consists of a reversal of the process just described. The acid which has been forced out of the plates into the electrolyte by the charging current again combines with the active material of the plates, when the cell is connected for discharge to produce a current. When the sulphuric acid in the electrolyte combines with the lead of the active material, a new compound, lead sulphate, is formed at both plates. This lead sulphate is formed in the same way that sulphuric acid, dropped on the copper-wire terminals, forms copper sulphate, or dropped on the iron work of the car, forms iron sulphate. In cases of this kind, it will always be noted that the amount of sulphate formed is all out of proportion to the quantity of metal eaten away. In the same manner, when the sulphuric acid of the electrolyte combines with the lead in the plates to form lead sulphate, the volume is such as to completely fill the pores of the active material when the cell is entirely discharged. This makes it difficult for the charging current to reach all parts of the active material and accounts for the manufacturers' instructions, never to discharge the battery below a certain point.

As the discharge progresses, the electrolyte becomes weaker by the amount of acid that is absorbed by the active material of the plates in the formation of lead sulphate, which is a compound of acid and lead. This lead sulphate continues to increase in bulk, filling the pores of the plates, and as these pores are stopped up by the sulphate, the free circulation of the acid is retarded. Since the acid cannot reach the active material of the plates fast enough to maintain the normal action, the battery becomes less active,

which is indicated by a rapid falling off in the voltage. Starting at slightly over 2 volts per cell when fully charged, this voltage will be maintained at normal discharge rates with but a slight drop, until the lead sulphate begins to fill the plates. As this occurs, the voltage gradually drops to 1.8 volts per cell and from that point on will drop very rapidly. A voltage of 1.7 volts per cell indicates practically complete discharge, or that the plates of the cell are filled with lead sulphate and that the battery should be placed on charge immediately.

During the normal discharge, the amount of acid used from the electrolyte will cause the specific gravity of the solution to drop 100 to 150 points, so that if the hydrometer showed a reading of 1.280 when the cell was fully charged, it will indicate but 1.130 to 1.180 when it is exhausted, or completely discharged. The electrolyte is then very weak; in fact, it is little more than pure water. Practically all of the available acid has been combined with the active material of the plates. While the acid and the lead combine with each other in difinite proportions in producing the current on discharge, it is naturally not possible to provide them in such quantities that both are wholly exhausted when the cell is fully discharged. Toward the end of the discharge, the electrolyte becomes so weak that it is no longer capable of producing current at a rate sufficient for any practical purpose. For this reason, an amount of acid in excess of that actually used in the plates during discharge is provided. This is likewise true of the active material.

Capacity of a Battery. The amount of current that a cell will produce on discharge is known as its capacity and is measured in ampere hours. It is impossible to discharge from the cell as much current as was needed to charge it, the efficiency of the average cell of modern type when in good condition being 80 to 85 per cent, or possibly a little higher when at its best, i.e., after five or six discharges. In other words, if 100 ampere hours are required to charge a battery, only 80 to 85 ampere hours can be discharged from it. This ampere-hour capacity of the cell depends upon the type of plate used, the area of the plate, and the number of plates in the cell, i.e., total positive-plate area opposed to total negative-plate area. To accomplish this, both outside plates in a cell are made negative. The ampere-hour capacity of a battery, all the

cells of which are connected up as a single series, is the same as that of any single cell in the series; as in connecting up dry cells in series, the current output is always that of a single cell, while the voltage of the current increases volts for each cell added to the series. In the case of the storage battery, it increases two volts for each cell.

The capacity of the cell as thus expressed in ampere hours is based on its normal discharge rate or on a lower rate. For example, take a 100-ampere-hour battery. Such a battery will produce current at the rate of 1 ampere for practically 100 hours, 2 amperes for 50 hours, or 5 amperes for 20 hours; but as the discharge rate is increased beyond a certain point, the capacity of the battery falls off. The battery in question would not produce 50 amperes of current for 2 hours. This is because of the fact that the heavy discharge produces lead sulphate so rapidly and in such large quantities that it quickly fills the pores of the active material and prevents further access of the acid to it. Thus, while it will not produce 50 amperes of current for 2 hours on continuous discharge, it will be capable of a discharge as great or greater than this by considerable, if allowed periods of rest between. When on open circuit, the storage battery recuperates very rapidly. It is for this reason that when trying to start the switch should never be kept closed for more than a few seconds at a time. Ten trials of 10 seconds each with a half-minute interval between them will exhaust the battery less than will spinning the motor steadily for a minute and forty seconds.

Fig. 454. Section of Willard Starting Battery, Showing Mud Space

Construction Details. For automobile starting and lighting service, the elements of the cells are placed in insulating supports in the bottom of the hard rubber jars and sealed in place. These supports hold the plates off the bottom of the jar several inches in the later types of starting batteries. Figs. 454 and 455 show sections of the Willard starter battery and another standard type This is known as the mud space and is designed to receive the accumulation of sediment consisting of the active material which is shaken off the plates in service. This active material is naturally a good electrical conductor, and if it were allowed to come in contact with the bottoms of the groups of plates, it would short-circuit the cell. Sufficient space is usually allowed under the plates to accommodate practically all of the active material that can be shed by the plates during the active life of the cell. In a battery having cells of this type, it is never necessary to wash the cells, as the elements themselves would require renewal before the sediment could reach the bottom of the plates.

Fig. 455. Typical Starting Battery with Plates Cut Down, Showing Assembly

In sealing the elements into the jar, a small opening is left for the purpose of adding distilled water as well as to permit the escape of the gas when the battery is charging. Except when being used for refilling the jars, this opening is closed by a soft rubber stopper which has a small perforation through which the hydrogen passes out of the cell when the latter is gassing, as explained later. The different cells of a battery are electrically connected by heavy lead straps, these strips being usually burned onto the plates by the lead-burning process.

Edison Cell Not Available. It will be noted that the foregoing description has been confined entirely to the lead-plate type of storage battery and that no mention has been made of the Edison cell. The latter is not available for starting service on the automobile, because its internal resistance is too high to permit the extremely heavy discharge rate that is necessary. In extremely cold weather or where the engine is unusually stiff for other reasons, this may be as high as 300 amperes momentarily, while, under ordinary conditions, it will reach 150 to 200 amperes at the moment of closing the switch. The efficiency of the Edison cell also drops off very markedly in cold weather, though this is also true to a lesser extent of the lead-plate type.

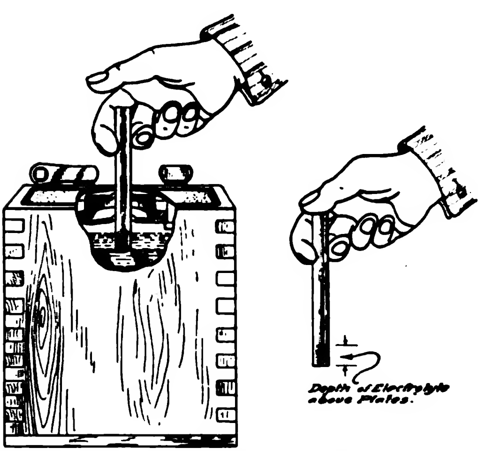


Fig. 456. Diagram Showing Method of Measuring Height of Electrolyte over Plates
Courtesy of U. S. Light and Heat Corporation, Niagara Falls, New York

CARE OF THE BATTERY

The following instructions are given about in the order in which it is necessary to apply them in the care of a storage battery.

Adding Distilled Water. In order to function properly, the plates in the cells must be covered by the electrolyte at all times to a depth of half an inch. Fig. 456 shows a handy method of determining this definitely. A small piece of glass tube, open at both ends, is inserted in the vent hole of the battery until it rests on the tops of the plates. A finger is then pressed tightly on top of the upper end of the tube, and the tube is withdrawn. It will bring with it at its lower end an amount of acid equivalent to the depth over the plates. This should always be returned to the same cell from which it was taken. The electrolyte consists of sulphuric acid and water. The acid does not evaporate, but the water does. The rapidity with which the water evaporates will depend upon the conditions of charging. For example, if a car is constantly driven on long day runs and gets very little night use, the storage battery is likely to be contin-

ually overcharged and may need the addition of water to the electrolyte as often as every three days, whereas, in ordinary service, once a week would be sufficient. Even with intermittent use, the battery should not be allowed to run more than two weeks without an inspection of the level of the electrolyte and the addition of distilled water, if necessary. Distilled water is always specified, since the presence of impurities in the water would be harmful to the battery, this being particularly the case where they take the form of iron salts. Where it is not convenient to procure distilled or rain water in sufficient quantities, samples of the local water supply may be submitted to any battery manufacturer for analysis.

While it is necessary to maintain the electrolyte one-half inch over the plates, care must be taken not to exceed this, for, if filled above this level, the battery will flood when charged, owing to the solution with the increasing temperature. The best time for adding water is just before the car is to be taken out for several hours of use. It may be done most conveniently with a glass and rubber syringe of the type used with the hydrometer. Care should be taken when washing the car to see that no water is allowed to enter the battery box, as it is likely to short-circuit the cells across their lead connectors and to carry impurities into the cells themselves.

Adding Acid. When the level of the electrolyte in the cell becomes low, it is, under normal conditions, caused by the evaporation of the water, and this loss should be replaced with water only. *There being no loss of acid, it should never be necessary to add acid to the electrolyte during the entire life of the battery.* When a jar leaks or is accidentally upset, and some of the solution lost, the loss should be replaced with electrolyte of the same specific gravity as that remaining in the cell, and not with full strength acid nor with water alone. The former would make the solution too heavy, while the latter would make it too weak. Consequently, unless acid is actually known to have escaped from the cell, none should ever be added to it. Under the sections on the Hydrometer and Specific Gravity, further reasons are given why no acid or electrolyte should be added to the cell under normal conditions, and the causes which would seem to make the addition of acid necessary are explained.

Hydrometer. Next to the regular addition of distilled water to the cells, the garage man will be called upon most frequently to

test the condition of the cells with the hydrometer. This is termed taking the specific gravity and is one of the most important tests in connection with the care of the battery. The specific gravity of a liquid is determined by means of an instrument consisting of a weighted glass tube having a scale marked on it. This instrument is the hydrometer, and in distilled water at 60 degrees it should sink until the scale comes to rest at the surface of the liquid at the division 1.000. The lighter the liquid, the further the instrument will sink in it; the heavier the liquid, the higher the instrument will float. For constant use in connection with the care of lighting and starting batteries, the hydrometer shown in Fig. 457 will be found the most convenient. Where the battery is located on the running board of the car, the test may be made without removing the syringe from the cell, but care must be taken to hold it vertical to prevent the hydrometer from sticking to the sides of the glass barrel. Wherever possible, the reading should be made without removing the syringe from the vent hole of the cell, so that the electrolyte thus withdrawn may always be *returned to the same cell.* Where the battery is located in a position difficult of access, as under the floor boards, the syringe may be drawn full of electrolyte and then lifted out; as the soft rubber plug in the bottom of the glass barrel is in the form of a trap, when the instrument is held vertical, the solution will not run out while the reading is being taken.

Fig. 457. Syringe Hydrometer Set

Failure to replace the electrolyte in the same cell from which it was taken will result in destroying the uniformity of the cells. For example, if electrolyte has been withdrawn from cell No. 1 of the battery and, after taking the reading, it is put into cell No. 2, the amount taken from No. 1 must later be made up by adding water, and the solution will be that much weaker, while the electrolyte of No. 2 will be correspondingly stronger.

Hydrometer Tests. In taking a hydrometer reading, first see that the instrument is not held by the sides of the glass syringe barrel; then note the level of the instrument in the liquid by looking at it from below, i.e., hold it up above the level of the eye. Reading the hydrometer in this way is found to give more accurate results than looking down upon it. While the hydrometer affords the best single indication of the condition of the battery—the cells should test 1.250 to 1.300 when fully charged and 1.150 when fully discharged, below which point they should never be allowed to go—there are conditions under which the instrument may be entirely misleading. For example, when fresh distilled water is added to a cell to bring the solution up to the proper level, the additional water does not actually combine with the electrolyte until the cell has been on charge for some time. Consequently, if a hydrometer reading were taken of that particular cell just after the water had been added, the test would be misleading, as it would apparently show the cell to be nearer the fully discharged state than it actually was, owing to the low specific gravity of the electrolyte. If, on the other hand, fresh electrolyte or pure acid has been added to a cell just prior to taking readings, and without the knowledge, of the tester the reading would apparently show the battery to be fully charged, whereas the reverse might be the case. In this instance, the specific gravity would be higher than it should be. To determine accurately the condition of the cells in such circumstances, the hydrometer readings would have to be checked by making tests with the voltmeter, as described later.

Under average conditions, however, the hydrometer alone will closely indicate the state of charge, and its use should always be resorted to whenever there is any question as to the condition of a battery. For instance, an irate owner will sometimes condemn the battery for failure of the starting motor to operate and will be absolutely positive that the battery has been fully charged, since he has been driving in daylight for hours. The hydrometer reading will show at once whether the battery is charged or not. If it is not, it will indicate either that the generator, its regulator, or the battery cut-out are not working properly, or that there is a short-circuit or a ground somewhere in the lighting or ignition circuits which permits the battery to discharge itself. Another more or less common complaint,

the cause of which may be definitely assigned one way or the other by the aid of the hydrometer is that "the battery is not holding its charge". Except where it is allowed to stand for long periods without use, as where a car is laid up for a month or more, there is no substantial decrease in the capacity simply through standing, unless the battery is allowed to stand in a discharged condition.

Consequently, the owner's impression that the charge of the battery is mysteriously leaking away overnight through some shortcoming of the cells themselves is not correct. If there is a fault, it is probably in the wiring; or a switch may have been left on inadvertently; or, as is very often the case, the car is not driven long enough in daylight to permit the generator to charge the battery sufficiently. When driving at night with all lights on, as is commonly the custom, the generator supplies very little current in excess of that required by the lamps. As a result, the battery receives but a fraction of its normal charge, so that one or two attempts to use the starting motor exhaust it. A hydrometer test made just before using the starting motor will show that there is only a small fraction of a charge in the cells, so that they are not capable of supplying sufficient current to turn the engine over longer than a few seconds. The hydrometer is equally valuable in indicating when a battery is being overcharged, though this is a condition which carries its own indication, known as gassing, which is described in detail under that head.

Variations in Readings. Specific-gravity readings between 1.275 and 1.300 indicate that the battery is fully charged; between 1.200 and 1.225, that the battery is more than half discharged; between 1.150 and 1.200, that the battery is quickly nearing a fully discharged condition and must be recharged very shortly, otherwise injury will result. Below 1.150 the battery is entirely exhausted and must be recharged immediately to prevent the plates from becoming sulphated, as explained in the section covering that condition.

Where the specific gravity in any cell tests more than 25 points lower than the average of the other cells in the battery, it is an indication that this cell is out of order. Dependence should not be placed, however, on a single reading where there is any question as to the specific gravity. Take several readings and average them. Variations in cell readings may be caused by internal short-circuits in the cell; by putting too much water in the cell and causing a loss

of electrolyte through flooding or overflowing; or by loss of electrolyte from a cracked or leaky jar. Internal short-circuits may result from a broken separator or from an accumulation of sediment in the mud space of the jars reaching the bottom of the plates.

Quite a substantial percentage of all the troubles experienced with starting batteries, which are only too often neglected until they give out, is caused by letting the electrolyte get too low in the jars. The effect of this is to weaken the battery, causing it to discharge more readily, and frequently resulting in harmful sulphating of the plates and injury to the separators. When such sulphating occurs, it permits the plates to come into contact with each other, and an internal short-circuit results. The importance of always maintaining the electrolyte one-half inch above the tops of the plates will be apparent from this.

One of the most frequent causes of low electrolyte in a single cell is the presence of a cracked or leaky jar. If one of the cells requires more frequent addition of water than the others to maintain the level of its electrolyte, it is an indication that it is leaking. Where all the cells of a battery require the addition of water at unusually short intervals, it is an indication that the battery is being constantly overcharged. (See Gassing.) Unless a leaky jar is replaced immediately, the cell itself will be ruined, and it may cause serious damage to the remainder of the battery. Jars are often broken owing to the hold-down bolts or straps becoming loose, thus allowing the battery to jolt around on the running board, or they may be broken by freezing. The presence of a frozen cell in a battery shows that it has been allowed to stand in an undercharged condition in cold weather, as a fully charged cell will not freeze except at unusually low temperatures.

Frozen Cells. In some cases, the cells may freeze without cracking the jars. This will be indicated by a great falling off in the efficiency of the cells that have suffered this injury, or in a totally discharged condition which cannot be remedied by continuous charging. In other words, the battery is dead and the plates are worthless except as scrap lead. In all cases where cells have been frozen, whether the jar has cracked or not, the plates must be replaced at once. It must always be borne in mind that low temperatures seriously affect the efficiency of the storage battery and that

care should be taken to keep it constantly in a charged condition. A variation in the temperature also affects the hydrometer readings themselves. The effect of the temperature on the hydrometer tests is explained under Adjusting the Specific Gravity.

Low Cells. When one cell of the battery tests more than 25 points below the specific gravity of the others, as shown by the average of several readings taken of each, it should be placed on charge separately from an outside source of current. This may be done without removing it from the car or disconnecting it from the other cells, since the charging leads may be clipped to its terminal posts. If no other facilities are available and direct-current service is at hand, use carbon lamps as a resistance in the manner illustrated on another page. As the normal charging rate of the average starting battery is 10 to 15 amperes or more, that many 32-c.p. carbon filament lamps may be used in the circuit. Where only alternating current is available, a small rectifier, as described under Charging from Outside Sources, will be found most convenient in garages not having enough of this work to warrant the installation of a motor-generator. After the low cell has been on charge for an hour or two, note whether or not its specific gravity is rising, by taking a hydrometer reading. If, after several hours of charging, its specific gravity has not risen to that of the other cells, it is an indication that there is something wrong with the cell, and it should be cut out. (See Replacing a Jar and Overhauling the Battery.)

Adjusting the Specific Gravity. Except in such cases as those mentioned under Hydrometer, where water has been added to the electrolyte just before testing, or electrolyte has been added without the knowledge of the tester, specific gravity of the electrolyte is the best indication of the condition of the cell, and the treatment to be given should always be governed by it. As explained in the section on Action on Charge and Discharge, the acid of the electrolyte combines with the active material of the plates to produce the current on discharge. The further the cell is discharged the more acid there will be in the plates, and the less in the solution. Consequently, low-gravity readings practically always mean lack of acid in the solution, and that implies lack of charge. Unless there is something wrong with the cell, charging will restore the acid to the electrolyte and bring the specific-gravity readings up to normal. In case a jar

is leaking or has been overturned and lost some of its electrolyte, no amount of charging will bring its specific gravity up to the proper point.

The gravity readings of the cells vary somewhat in summer and winter, and they also decrease with the age of the plates, but the battery will continue to give good service as long as its specific gravity rises to between 1.250 and 1.300 when fully charged. In case it rises above 1.300, there is an indication that excess acid has been added to the electrolyte, and this must be corrected by drawing off some of the electrolyte with the syringe and replacing it with distilled water. A gradually decreasing specific gravity in all the cells of a battery is an indication that sediment is accumulating in the bottom of the jars and that the battery, if of the old type with low mud space, requires washing; if of the later type with high mud space, that its elements require renewal. Before accepting this conclusion, however, make certain that the low reading is not due to insufficient charging. In actual practice, starter batteries seldom remain long enough in service without overhauling even to need washing.

Many starter batteries are kept in an undercharged condition so constantly, owing to frequent use of the starting motor with but short periods of driving in between, that they should be put on charge from an outside source at regular intervals. In fact, this is the only method of determining definitely whether the battery itself is really at fault or whether it is the unfavorable conditions under which it is operating. Where the cells give a low reading, no attempt should ever be made to raise the specific gravity of the electrolyte by adding acid, until the battery has been subjected to a long slow charge. The maximum specific gravity of the electrolyte is reached when all the acid combined in the active material of the plates has been driven out by the charging current. Adding acid will increase the specific gravity, but it will not increase the condition of charge; it will simply give a false indication of a charged condition. For example, if the electrolyte of a cell tested 1.225, and, without giving it a long charge, acid were added to bring the specific gravity up to 1.275, it would then rise to 1.325 if put on charge, showing that 50 points of acid had remained combined in the plates when the low readings were taken.

The necessity for adjusting the specific gravity of the electrolyte in a cell can only be determined by first bringing it to its true maximum. To do this with a starter battery, it must be put on charge from an outside source at a low rate, say 5 amperes, and kept on charge continuously until tests show that the specific gravity of the electrolyte has ceased to rise. This may take more than twenty-four hours, and readings should be taken every hour or so, toward the end of the charge. Should the battery begin to gas violently while tests show that the specific gravity is still rising, the charging current should be reduced to stop the gassing, or, if necessary, stopped altogether for a short time and then renewed.

If after this prolonged charge, the specific gravity is not more than 25 points below normal, some of the solution may be drawn off with the syringe and replaced with small quantities of 1.300 electrolyte, which should be added very gradually to prevent bringing about an excess. Should the specific gravity be too high at the end of the charge, draw off some of the electrolyte and replace it with distilled water to the usual level of one-half inch over the plates. A charge of this kind is usually referred to as a conditioning charge and, given once a month, will be found very greatly to improve starter batteries that are constantly undercharged in service.

Temperature Corrections. All specific-gravity readings mentioned are based upon a temperature of 70° F. of the electrolyte, and as the electrolyte, like most other substances, expands with the heat and contracts with the cold, its specific gravity is affected by variations of temperature. This, of course, does not affect its strength, but as its strength is judged by its specific gravity, the effect of the temperature must be taken into consideration when making the tests. The temperature in this connection is not that of the surrounding air but that of the electrolyte itself, and as the plates and solution of a battery increase in temperature under charge, the electrolyte may be 70° F. or higher, even though the outside air is close to zero. Consequently, the only method of checking this factor accurately is to insert a battery thermometer in the vent hole of the cell. If, on the other hand, the battery has been standing idle for some time in a cold place, the electrolyte has the same temperature as the surrounding air, and a hydrometer reading taken without a temperature correction would be very misleading.

For example, assume that the car is standing in a barn in which the temperature is 20° F. and that it has not been running for some time so that the electrolyte is as cold as the surrounding air. A hydrometer reading shows the specific gravity of the electrolyte to be 1.265, which would indicate that the battery was approximately fully charged. But the correction for temperature amounts to one point (.001) for each three degrees above or below 70° F., and in this case a difference of 50 degrees would have to be allowed for. This amounts to practically 18 points, and the specific gravity of the cells is 1.265 minus 18, or 1.247. The battery is accordingly three-quarters charged, instead of fully charged as the uncorrected reading would appear to indicate. The electrolyte contracts with the drop in temperature, and its specific gravity becomes correspondingly higher without any actual increase in its strength. The opposite condition will be found when the battery has commenced to gas so violently that the temperature of the electrolyte is raised to 100° to 105° F. At the former figure there would be a difference of 30 degrees, or 10 points, to allow for, in which case a specific gravity reading of 1.265 would actually be 1.275. Hydrometer scales, with a a temperature scale showing at a glance the corresponding correction necessary, simplify the task of correcting the readings; but to do this properly a battery thermometer must be employed, as the temperature of the electrolyte itself is the only factor to be considered.

Gassing. When an electric current is sent through a storage-battery cell, it immediately attacks the lead sulphate into which the active material of both the positive and the negative plates has been converted during the discharge and begins to reconvert it into peroxide of lead at the positive plate and into spongy metallic lead at the negative. As long as there is an ample supply of this lead sulphate on which the current may work, as in a fully discharged battery, the entire amperage being sent through the battery is restricted to carrying on this process. In other words, the current will always do the easiest thing first by following the path of least resistance. When the cell is in a discharged state, the easiest thing to do is to decompose the lead sulphate. As there is a comparatively large amount of this lead sulphate in a fully discharged battery, a correspondingly large amount of current can be used in charging at the start. But as the amount of sulphate progressively decreases with the charge,

a point is reached at which there is no longer sufficient sulphate remaining to utilize all the current that is passing through the cell.

The excess current will then begin to do the next easiest thing, which is to decompose the water of the electrolyte and liberate hydrogen gas. This gassing is not owing to any defect in the battery, as some owners seem to think, but is simply the result of overcharging it. In one instance, a car owner condemned the starting battery with which his machine was equipped, for the reason that it was "always boiling". In fact, it "boiled" itself to pieces and had to be replaced by the manufacturer of the car after only a few months of service; while, as a matter of fact, the conditions under which the car was driven were wholly responsible. It was used for long runs in the day time with infrequent stops, and was rarely run at night; therefore, the battery was continually charging but seldom had an opportunity to discharge.

This erroneous impression is also closely interlinked with another that is equally common and equally harmful. This is that one of the functions of the battery cut-out is to break the circuit and prevent the battery from becoming overcharged. It is hardly necessary to add that this is not one of its functions, but that as long as the generator is being driven above a certain speed, the cut-out will keep the battery in circuit, and the generator will continue to charge it. Its only purpose is to prevent the battery from discharging itself through the generator when the speed of the generator falls to a point where its voltage would be overcome by that of the battery unless the battery were automatically disconnected. The cut-out does not protect the battery from being overcharged; only the driver or the garage man can do that by noting the conditions under which the car is operated and taking precautions to prevent the battery from overcharging.

Gassing is simply an indication that too much current is being sent into the battery. Another indication of the same condition is the necessity for refilling the cells with distilled water at very short intervals, as an excess charge raises the temperature of the electrolyte and causes rapid losses by evaporation. That is the reason why it is likely to be so harmful to the battery unless remedied, as if allowed to exceed 110° F., the active material is likely to be forced out of the grids, and the cells to be ruined. While it is essential

that the battery be fully charged at intervals and that it be always kept well charged, continuously overcharging it is likely to be as harmful as allowing it to stand undercharged. Where the conditions of service cannot be altered to remedy the trouble, the regulator of the generator should be adjusted to lower the charging rate, or, if nothing else will suffice, additional resistance, controlled by an independent switch, may be inserted in the charging circuit. (The U.S.L. system has a provision to safeguard the battery against overcharge, termed the touring switch.)

Higher Charge Needed in Cold Weather. While the regulator of the generator is set by the manufacturer to give the best average results, and some makers warn the user against altering its adjustment, experience has demonstrated that a fixed adjustment of the regulation will not suffice for cars driven under all sorts of service conditions, nor for the same car as used at different seasons of the year. The efficiency of the storage battery is at its lowest in cold weather, which is the time when the demand upon it is greatest. A battery that would be constantly overcharged during the summer may not get more than sufficient current to keep it properly charged in winter, though driven under similar conditions in both seasons. On the other hand, a battery that is generally undercharged under summer conditions of driving will be practically useless in winter, as it will not have sufficient current to meet the demands upon it.

It may be put down as a simple and definite rule that if the battery of a starting system never reaches the gassing stage, it is constantly undercharged and is rapidly losing its efficiency, as the sulphate remaining on the plates becomes harder with age and prevents the circulation of the electrolyte. Even when in the best condition, the electrolyte cannot reach all of the active material in the plates, so that any reduction means a serious falling off. Likewise, when a battery is constantly gassing, it is in a continuous state of overcharge and is apt to be entirely ruined in a comparatively short time. The danger from undercharging is known as sulphating—the plates become covered with a hard coating of lead sulphate that the electrolyte cannot penetrate—while that from overcharging is due to the electrolyte and the plates reaching a dangerous temperature (105° F. or over) at which the active material is apt to be stripped from the grids. The conditions of service, on the average, are such

that a battery can seldom be kept in good condition for any length of time on the charging current from the generator alone.

The hydrometer should be used frequently to keep track of its condition and, at least once a month, it should be given a long conditioning, or equalizing, charge, as it is variously termed. This charge is required because of the fact that, under ordinary conditions, a battery seldom receives a complete charge and that every time it is discharged without this being followed by a charge which is prolonged until the electrolyte has reached its maximum specific gravity, more lead sulphate accumulates in the plates. The object of the long charge is to convert this lead sulphate into peroxide of lead at the positive plate and into spongy metallic lead at the negative plate, as explained further under the head of Sulphating.

Sulphating. At the end of a discharge, both sets of plates are covered with lead sulphate. This conversion of the active material of the plates into lead sulphate, which takes place during the discharge, is a normal reaction and, as such, occasions no damage. But if the cells are allowed to stand for any length of time in a discharged condition, the sulphate not only continues to increase in bulk, but becomes hard. It is also likely to turn white, so that white spots on the plates of a battery when it is dismantled are an indication that the cells have been neglected. In this condition, the plates have lost their porosity to a certain extent and it is correspondingly more difficult for the charging current to penetrate the active material. When a battery has stood in a discharged condition for any length of time, it becomes sulphated. The less current it has in it at the time and the longer it stands, the more likely it is to be seriously damaged.

Where a car is used but little in the daytime, and then only for short runs with more or less frequent stops, the battery never has an opportunity to become fully charged. The demands of the starting motor and the lights are such that the battery is never more than half charged at any time. Consequently, there is always a certain proportion of the lead sulphate that is not reconverted, but which remains constantly in the plates. As already mentioned, this condition does not remain stationary; the sulphate increases in amount and the older portions of it harden. This represents a loss of capacity which finally reaches a point where the cells are

no longer capable of supplying sufficient current (holding enough of the charge, as the owner usually puts it) to operate the starting motor. A battery that has been operating under conditions of this kind is not prepared for the winter's service, which accounts for the great number of complaints about the poor service rendered by starting systems in the early part of every winter. As long as the weather is warm, the battery continues to supply sufficient current in spite of the abuse to which it is subjected, but when cold weather further reduces its efficiency, it is no longer able to meet the demand.

The only method of preventing this and of remedying it after it has occurred is the equalizing charge metioned in the preceding section. Long continued and persistent charging at a low rate will cure practically any condition of sulphate, the time necessary being proportionate to the degree to which it has been allowed to extend. It is entirely a question of time, and, as a high rate would only produce gassing, which would be a disadvantage, the rate of charge must be low. In case the cells show any signs of gassing, the charge must be further reduced.

Extra Time Necessary for Charging. The additional length of time necessary for charging a battery that has been constantly kept in an undercharged condition is strikingly illustrated by the following test made with an electric vehicle battery: The cells were charged to the maximum, and the specific gravity regulated to exactly 1.275 with the electrolyte just ½ inch above the tops of the plates, this height being carefully marked. The battery was then discharged and recharged to 1.265 at the normal rate in each case. The specific gravity rose from 1.265 to 1.275 during the last hour and a half of the charge. During the following twelve weeks, the battery was charged and discharged daily, each charge being only to 1.265, thus leaving 10 points of acid still in the plates. At the end of the twelve weeks, the charge was continued to determine the time required to regain the 10 points and thus restore the specific gravity to the original 1.275. Eleven hours were needed, as compared with the hour and half needed at first. This test further illustrates why it is necessary to give a battery an occasional overcharge or equalizing charge to prevent it becoming sulphated. Had the battery in question been charged daily to its maximum of 1.275 and discharged

to the same extent during the twelve weeks, 9½ hours of the last charge would have been saved. These periods of time, of course, refer to the charging of the electric-vehicle battery, but they indicate in a corresponding manner the loss of efficiency suffered by the starting battery owing to its being continually kept in an undercharged condition.

Restoring Sulphated Battery. There are only three ways in which a battery may become sulphated: The first and most common of these is that it has not been properly charged; second, excess acid has been added to the electrolyte; third, an individual cell may become sulphated through an internal short-circuit or by drying out, as might be caused by failure to replace evaporation with water, or failure to replace promptly a cracked jar. The foregoing only holds good, however, where the sediment has not been allowed to reach the bottom of the plates, and where the level of the electrolyte has been properly maintained by replacing evaporation with distilled water.

To determine whether a battery is sulphated or not—it having been previously ascertained that it does not need cleaning (washing)—it should be removed from the car (the generator should not be run with the battery off the car without complying with the manufacturer's instructions in each case, usually to short-circuit or bridge certain terminals on the generator itself) and given an equalizing charge at its normal rate. The normal rate will usualy be found on the name plate of the battery. If the battery begins to gas at this rate, the rate must be reduced to prevent gassing, and lowered further each time the cells gas. Frequent hydrometer readings should be taken, and the charge should be continued as long as the specific gravity continues to increase. A battery is sulphated only when there is acid retained in the plates. When the specific gravity reaches its maximum, it indicates that there is no more sulphate to be acted upon, since, during the charge, the electrolyte receives acid from no other source. With a badly sulphated battery, the charge should be continued until there has been no further rise in the specific gravity of any of the cells for a period of at least twelve hours. Maintain the level of the electrolyte at a constant height by adding pure water after each test with the hydrometer (if water were added just before taking readings, the water would rise to the top of the solution

and the reading would be valueless). With a battery on a long charge, the battery thermometer should be used at intervals to check the temperature of the electrolyte, and the hydrometer readings should be corrected in accordance with the temperature.

Specific Gravity too High. Should the specific gravity of any of the cells rise above 1.300, draw off the electrolyte down to the top of the plates and put in as much distilled water as possible without flooding the cell. Continue the charge and, if the specific gravity again exceeds 1.300, this indicates that acid has been added during the previous operation of the battery. The electrolyte should then be emptied out and replaced with distilled water and the charge continued. The battery can only be considered as restored to efficient working condition when there has been no rise in the specific gravity of any of the cells during a period of at least twelve hours of continuous charging.

Upon completion of the treatment, the specific gravity of the electrolyte should be adjusted to its proper value of 1.280, using distilled water or 1.300 acid, as necessary. In cases where one cell has become sulphated while the balance of the battery is in good condition, it is usually an indication that there is a short-circuit or other internal trouble in the cell, though this does not necessarily follow. To determine whether or not it is necessary to dismantle the cell, it may first be subjected to a prolonged charge, as above described. If its specific gravity rises to the usual maximum, the condition may be considered as remedied without taking the cell apart. It is the negative plate which requires the prolonged charge necessary to restore a sulphated battery. When sulphated, the active material is generally of light color and either hard and dense or granular and gritty, being easily disintegrated. Unless actually buckled or stripped of considerable of their active material, the positive plates are unchanged in appearance and can be restored to operative condition, though their life will be shortened by this abuse. Sulphated plates of either type should be handled as little as possible. By keeping close check with the hydrometer on the condition of the starting battery and, where it is not being kept in an overcharged condition constantly, giving it an equalizing charge once a month, the charge being continued until the cells no longer increase in specific gravity after a period of several hours, and the

reading of all the cells being within at least 25 points of each other, sulphating may be avoided entirely.

Internal Damage. This trouble is usually caused by a short-circuit, owing either to an accumulation of sediment reaching the plates or to the breaking of a separator, which may be caused by the active material being forced out of the grid, usually termed buckling, which is caused by overheating. It is important to be able to determine whether or not the low efficiency of a certain cell is caused by internal trouble without having to dismantle the cell. The repair man's most important aid for this class of work is the high-grade portable voltmeter mentioned in connection with other tests of the starting and lighting system.

Voltage Tests. Under some conditions, the voltmeter will also indicate whether the battery is practically discharged or not, but, like the hydrometer, it should not be relied upon alone. To insure accuracy, it must be used in conjunction with the hydrometer. Since a variation as low as .1 (one-tenth) volt makes considerable difference in what the reading indicates regarding the condition of the battery, it will be apparent that a cheap and inaccurate voltmeter would be a detriment rather than an aid. The instrument illustrated in connection with tests of other parts of starting and lighting systems (see Delco) is of the type required for this service. Complete instructions for its use will be received with the instrument, and these must be followed very carefully to avoid injuring it. For example, on the three-volt scale, but one cell should be tested; attempting to test the voltage of more than one cell on this scale is apt to burn out the three-volt coil in the meter. The total voltage of the number of cells to be tested must never exceed the reading of the particular scale being used at the time; otherwise, the coil of the scale in question will suffer, and the burning out of one coil will make it necessary to rebuild the entire instrument.

Clean Contacts Necessary. Where the voltage to be tested is so low, a very slight increase in the resistance will affect it considerably and thus destroy the accuracy of the reading. Make certain that the place on the connector selected for the contact point is clean and bright, and press the contact down on it firmly. To insure a clean bright contact point, use a fine file on the lead connector. The contact will be improved by filing the test points fairly sharp.

Even a thin film of dirt or a weak contact will increase the resistance to a point where the test is bound to be misleading. The positive terminal of the voltmeter must be brought into contact with the positive terminal of the battery, and the negative terminal of the voltmeter with the negative of the battery. If the markings of the cell terminals are indistinct, connect the voltmeter across any one cell. In case the pointer butts up against the stop at the left instead of giving a reading, the connections are wrong and should be reversed; if the instrument shows a reading for one cell, the positive terminal of the voltmeter is in contact with the positive of the battery. This test can be made with a voltmeter without any risk of short-circuiting the cell, as the voltmeter is wound to a high resistance and will pass very little current. Connecting an ammeter directly across a cell, however, would short-circuit it and instantly burn out the instrument.

How to Take Readings. It is one of the peculiarities of the storage cell that when on "open circuit", i.e., not connected in circuit with a load of any kind, it will always show approximately two volts, regardless of whether it is almost fully charged or almost the reverse. Consequently, voltage readings taken when the battery is on open circuit, i.e., neither charging nor discharging, are valueless, *except when a cell is out of order*. Therefore, a load should be put on the battery before making these tests. This can be done by switching on all the lamps. With the lights on, connect the voltmeter, as already directed, and test the individual cells. If the battery is in good condition, the voltage readings, after the load has been on for about ten minutes, will be but slightly lower than if the battery were on open circuit. This should amount to about .1 (one-tenth) volt. Should one or more of the cells be completely discharged, the voltage of these cells will drop rapidly when the lamps are first switched on and, when a cell is out of order, will sometimes show a reverse reading. Where the battery is nearly discharged, the voltage of each cell will be considerably lower than if the battery were on open circuit, after the load has been on for five minutes.

Detecting Deranged Cells. To distinguish the difference between cells that are merely discharged and those that are out of order, put the battery on charge, either from an outside source or by starting the engine, which should always be cranked by hand

when any battery trouble is suspected. Then test again with the voltmeter. If the voltage of each cell does not rise to approximately two volts after the battery has been on charge for ten minutes or more, it is an indication of internal trouble which can be remedied only by dismantling the cell. (See instructions under that heading.)

Temperature Variations in Voltage Test. When making voltage tests, it must be borne in mind that the voltage of a cold battery rises slightly above normal on charge and falls below normal on discharge. The reverse is true of a warm battery in hot weather, i.e., the voltage will be slightly less than normal on charge and higher than normal on discharge. As explained in connection with hydrometer tests of the electrolyte, the normal temperature of the electrolyte may be regarded as 70° F., but this refers only to the temperature of the liquid itself as shown by the battery thermometer, and not to the temperature of the surrounding air. For the purpose of simple tests for condition, voltage readings on discharge are preferable, as variations in readings on charge mean little except to one experienced in the handling of storage batteries.

Joint Hydrometer and Voltmeter Tests. As already explained above, neither the hydrometer nor the voltmeter reading alone can always be taken as conclusive evidence of the condition of the battery. There are conditions under which one must be supplemented by the other to obtain an accurate indication of the state of the battery. In making any of the joint tests described below, it is important to take into consideration the four points following:

(1) The effect of temperature on both voltage and hydrometer readings.

(2) Voltage readings should be taken only with the battery discharging, as voltage readings on an idle battery in good condition indicate little or nothing.

(3) Never attempt to use the starting motor to supply a discharge load for the battery, because the discharge rate of the battery is so high while the starting motor is being used that even in a fully charged battery it will cause the voltage to drop rapidly.

(4) The voltage of the charging current will cause the voltage of a battery in good condition to rise to normal or above the moment it is placed on charge, so that readings taken under such circumstances are not a good indication of the condition of the battery.

In any battery which is in good condition, the voltage of each cell at a normally low discharge rate, i.e., 5 to 10 amperes for a starter battery of the 6-volt type or slightly less for a higher voltage battery, will remain between 2.1 and 1.9 volts per cell until it begins to approach the discharged condition. A voltage of less than 1.9 volts per cell indicates either that the battery is nearly discharged or is in a bad condition. The same state is also indicated when the voltage drops rapidly after the load has been on for a few minutes. The following joint hydrometer and voltmeter tests issued by the Prest-O-Lite Company of Indianapolis will be found to cover the majority of cases met with in actual practice.

(1) A voltage of 2 to 2.2 volts per cell with a hydrometer reading of 1.275 to 1.300 indicates that the battery is fully charged and in good condition.

(2) A voltage reading of less than 1.9 volts per cell, with a hydrometer reading of 1.200 or less indicates that the battery is almost completely discharged.

(3) A voltage reading of 1.9 volts or less per cell, with a hydrometer reading of 1.220 or more, indicates that excess acid has been added to the cell. Under these conditions, lights will burn dimly, although the hydrometer reading alone would appear to indicate that the battery was more than half charged.

(4) Regardless of voltage—high, low, or normal—any hydrometer reading of over 1.300 indicates that an excessive amount of acid has been added.

(5) Where a low voltage reading is found, as mentioned in cases 2 and 3, to determine whether the battery is in bad order or merely discharged, stop the discharge by switching off the load, and put the battery on charge, cranking the engine by hand, and note whether the voltage of each cell rises promptly to 2 volts or more. If not, the cell is probably short-circuited or otherwise in bad condition.

Cleaning a Battery. Electric vehicle batteries usually receive such careful and intelligent attention that the life of the battery is measured by the maximum number of charges and discharges of which the plates are capable under favorable conditions. To prevent any possibility of short-circuiting, a cell is cut out and opened after a certain number of discharges, and if the amount of sediment in the jar is approaching the danger point, the entire battery is opened and cleaned. With the old type starter cell, this would be necessary if the battery received the proper attention; with the modern or high mud-space type, cleaning is never necessary as the space is designed to accommodate all the active material that can fall from the plates without touching their under sides. As a matter of fact, the batteries of starting and lighting systems never last long enough to require cleaning out. They are either kept undercharged and

thus become badly sulphated, or they are overcharged to a point where the temperature passes the danger mark frequently. When hot, the acid attacks and injures the wood separators so that the average life is about one year. Exceptions to this are found in those cases where the battery has been given proper attention, which results in unusually long life without the necessity of opening the cells for either cleaning or the insertion of new separators. These cases are so in the minority, however, that the battery manufacturers usually recommend that the car owner have his starting battery overhauled in the fall to put it in the best of condition for the winter as well as for the following year. Even where a battery has been

Fig. 458. Drilling Off Connectors
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

given conscientious attention, the conditions of charging on the automobile are likely to vary so radically that it will be found almost impossible to keep the cells in a good state. Consequently, it is considered the best practice to give all starter batteries an overhauling once a year. The method of doing this is described in succeeding sections.

Replacing a Jar. When a cell requires the addition of distilled water more often than the other cells of the battery, or does not test to the same specific gravity as the others, it is usually an indication that there is a leak in the jar. Failure to give the same specific-gravity reading is not proof of this condition, as the cell may be

low from other causes, but the loss of electrolyte is certain evidence of it. The only remedy is to replace the jar at fault.

After locating the cell in question, carefully mark the connectors so as to be sure to replace them the same way. Disconnect the cell from the others in the battery. This may be done either with the aid of brace and bit, which is used to drill down through the post of the connector, Fig. 458, or with a gasoline torch which should be applied carefully to the strap at the post. When the metal has become molten, pry the strap up on the post with a piece of wood. Do not use a screwdriver or other metal for this purpose as it is apt to short-circuit one or more of the cells. Care must also be taken not to apply so much heat that the post itself will be melted as this would make it difficult to reconnect the cell. For one not accustomed to handling the torch, it will be safer to drill out the post, as illustrated. Lift the complete cell out of the battery box and then use the torch to warm the jar around the top to soften the sealing compound that holds the cover, Fig. 459. Grip the jar between the feet, take hold of the two connectors and pull the element almost out of the jar, Fig. 460. Then grip the elements near the bottom to prevent the plates flaring out while transferring them to the new jar, taking care not to let the outside plates start down the outside of the jar, Fig. 461. After the element is in the new jar, reseal the cell by pressing the sealing compound into place with a hot putty knife. Fill the cell with 1.250 electrolyte to the proper point, the old electrolyte being discarded.

Fig. 459. Softening Sealing Compound on Cell

Before replacing the connectors, clean both the post and the inside of the eye of the connector by scraping them smooth with a knife. When the connector has been placed in position, tap it down firmly over the post to insure good contact. To complete the connection, melt the lead of the connector and the post at the top so that they will run together, and while the lead is still molten,

melt in some more lead until the eye of the connector is filled level. This is termed lead burning and is described at greater length in a succeeding section. Where no facilities are at hand for carrying it out, it may be done with an ordinary soldering copper. The copper is brought to a red heat so that all the tinning is burned off, and no flux of any kind is used. The method of handling the soldering copper and the lead-burning strip to supply the extra metal required to fill the eye is shown in Fig. 462.

Fig. 460. Lifting Elements out of Jar by Hand

Fig. 461. Installing Elements in Jar

Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

Put the battery on charge from an outside source, and when the cells begin to gas freely, reduce the current to half the finishing rate given on the battery name plate and charge at this rate as long as there is any rise in the specific gravity of the electrolyte in this or any of the other cells. The maximum gravity has been reached when there has been no rise in the specific gravity for a period of three hours. If the gravity of the cell having the new jar is then over 1.280, draw off some of the electrolyte and replace it with distilled water. If the gravity is below 1.270, draw off some of the electrolyte and replace it with 1.300 electrolyte. If necessary

to put in 1.300 electrolyte, allow the battery to continue charging for about one-half hour longer at a rate sufficient to cause gassing, which will cause the stronger acid to become thoroughly mixed with the rest of the electrolyte in the cell.

Overhauling the Battery. As already mentioned, it will be found desirable to overhaul the majority of starter batteries at least once a year. The expense to the car owner will be less than

Fig. 462. Reburning Battery Connectors with Soldering Iron
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

the cost of the frequent attention required by a run-down battery with complete renewal at no distant date, and the service rendered by the battery will be much improved. The best time of year to do this is in the late fall, so that the battery may be at its best during the cold weather. Before undertaking the work, have on hand a complete renewal set of rubber and wood separators as well as sufficient fresh acid of 1.300 specific gravity with which to mix fresh electrolyte. Use the good separators, particularly the rubber ones.

Dismounting Cells. Remove the connectors by drilling, heating, or pulling (in the same manner as a wheel is pulled), and loosen the jar covers by heating or running a hot putty knife around their edges so that they may be lifted off. The covers should be washed in hot water and then stacked one on top of the other with heavy weight on them to press them flat. Lift the jars out of the battery box and note whether any of them have been leaking. A cracked jar should of course be replaced. Treat one cell at a time, by pulling the element out of the jar with the aid of the pliers, meanwhile holding the jar with the feet. Lay the element on the bench and

Fig. 463. Removing Old Separators from Elements

Fig. 464. Pressing Negative Group

Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

spread the plates slightly to permit removing the separators, taking care not to injure the rubber sheets, Fig. 463. Separate the positive group from the negative. If the active material of the negative be swollen beyond the surface of the grid, press it back into position before it has a chance to dry, placing boards of suitable thickness between the plates and carefully squeezing the group between heavy boards in a vise or press, as shown in Fig. 464. Boards of sufficient size and thickness must be used between the plates or breakage will result. Charged negative plates will become hot in a short time when exposed to the air and, in this event, should be allowed to cool before reassembling. Remove any loose particles adhering

to the positive plates by passing a smooth wood paddle over the surface but *do not wash the positive plates.*

Treating the Plates. If the positive plates show signs of buckling or stripping of the active matter, or if the negative plates have the light spotted appearance indicative of sulphating, it may be necessary to replace them altogether. In case sulphating appears to be the only trouble, the groups should be reassembled in an open jar with distilled water and given a long, slow charge, testing with the hydrometer at frequent intervals to note whether the specific gravity is rising or not. Twenty-four hours or more may be necessary for this charge, and two or three days will be nothing unusual. This charging, of course, is carried on from the lighting mains through a rectifier or a motor-generator, unless direct-current service is available. If it is necessary to prolong the charge over two or three days, and the specific gravity still continues to rise slowly, it may be preferable to replace the plates.

Reassembling Battery. Wash all the sediment out of the jars, also wash and save the rubber sheets, unless they happen to be broken, but throw away the old wood separators. The rubber sheets should be placed in clean running water for about a quarter of an hour. Reassemble the positive and negative groups with the plates on edge in order to insert the separators. Place a rubber separator against the grooved side of a wood separator, Fig. 465, and insert a positive plate near the center of the element. The rubber sheet must be against the positive plate, and the wood separator against the negative plate. In this manner insert separators in all the spaces, working in both directions from the center. Care must be taken *not to omit a separator as that would short-circuit the cell.*

Fig. 465. Wood and Rubber Separator

The separators should be practically flush with the bottoms of the plates to bring their tops against the hold-down below the strap, and must extend to or beyond the side edge of the plates. Grip the element near the bottom to prevent the plates flaring out while placing the element in the jar. Fill the cell to within one-half inch of the top of the jar, using electrolyte of 1.250 specific gravity. If the negative plates show signs of sulphating, but not enough to call for the special treatment mentioned above, use water instead of the electrolyte. After all of the cells have been given the same treatment and reassembled, return them to the battery box in their proper positions, so that the positive of each cell will be connected to the negative of the adjoining cell and connect temporarily by pressing the old connecting straps in place by hand.

Checking the Connections. Put the battery on charge at its finishing rate (usually about 5 amperes) and, after charging about fifteen minutes, note the voltage of each cell. This is to insure having reconnected the cells properly with regard to their polarity. If this be the case, they should all read approximately 2 volts. Any cell that reads less is likely to have been connected backward. When the cells begin to gas freely and uniformly, take a hydrometer reading of each cell and a temperature reading of one of them. Reduce the current to one-half the finishing rate. Should the temperature of the electrolyte reach 100° F., reduce the charge, or interrupt it temporarily, to prevent the cells getting any hotter. Both hydrometer and temperature readings must be taken at regular intervals, say four to six hours apart, to determine if the specific gravity is still rising or if it has reached its maximum. Continue the charge and the readings until there has been no further rise for a period of at least twelve hours. Maintain the height of the electrolyte constant by adding water after each reading. (If water were added before the reading, it would not have time to mix with the electrolyte, and the reading would not be correct.)

Should the specific gravity rise to about 1.300 in any cell, draw off the electrolyte down to the level of the tops of the plates and refill with as much water as possible without overflowing. Continue the charge, and if the specific gravity again exceeds 1.300, dump out all the electrolyte in that cell, replace it with water, and continue the charge. The charge can be considered complete only when

there has been no rise in the gravity of any of the cells during a period of at least twelve hours of continuous charging. Upon completion of the charge, the electrolyte should have its specific gravity adjusted to its proper value (1.270 to 1.280) using water or 1.300 acid, as may be necessary, and the level of the electrolyte adjusted to a uniform ½ inch above the plates.

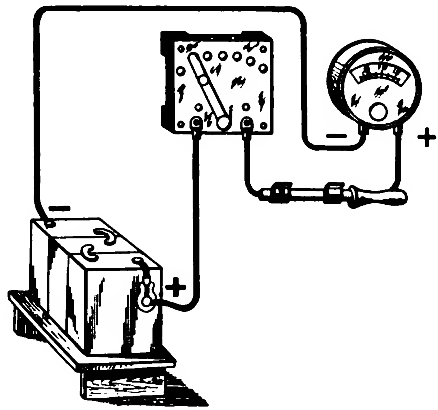


Fig. 466. Wiring Diagram for Discharging Battery through Rheostat

Discharge the battery at its normal discharge rate to determine if there are any low cells caused by defective assembly. The normal discharge rate of the battery is usually given on its name plate. To discharge the battery, the current may be passed through a rheostat, as in Fig. 466, or if no panel board of this type be available, through a water resistance, as shown in Fig. 467. The resistance of a water rheostat increases with the distance between its plates and decreases according to their proximity and to the degree of conductivity of the water itself. If the resistance is too high with the plates close together, add a little acid to the water. It will be necessary, of course, to have an ammeter in the circuit to show the rate at which the battery is discharging. In case any of the cells are low, owing to being assembled defectively or connected with their polarity reversed, as shown

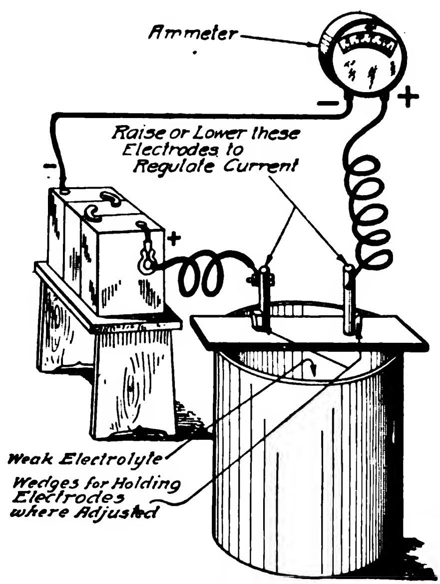


Fig. 467. Wiring Diagram for Discharging Battery through Water Resistance

by the voltmeter test (they should all register two volts or slightly over at the beginning of the discharge and should fall off slowly) such cells should be remedied at once. Recharge the battery and then remove the temporary connectors, wipe the inside edges of the jars dry, and put the rubber covers in place. Heat the sealing compound which is supplied for this purpose and apply around the edges of the covers, smoothing it down with a hot putty knife. Care must be taken not to burn the sealing compound when heating it.

Reconnecting Cells. If the old lead connecting straps have been removed carefully, they may be used again, though in many cases it will be found preferable to employ new straps. Before putting the straps in place, scrape the posts clean with a knife and clean out the eyes of the straps themselves. When the connectors have been put in place, tap them down firmly to insure good contact. Before reburning the connectors in place, test each cell with a low-reading voltmeter to make certain that the cells have been connected in the right direction, i.e., that their polarity has not been reversed. It is not sufficient to note that the voltage of each cell is correct, i.e., 2 volts per cell or over, but care must be taken also to note that it is in the right direction. With a voltmeter having a needle that moves in both directions from zero, one polarity will be evidenced by the needle moving over the scale to the right of the neutral line, while if the polarity be reversed, the needle will move to the left. One cell having the proper polarity should accordingly be tested and then, to be correct, the remaining cells should cause the needle to move in the same direction and to approximate the same voltage when the instrument leads are held to the same terminals in the same way for each. Where the voltmeter needle can move in but one direction, i.e., to the right, a change of polarity will be indicated by the needle of the instrument attempting to move to the left and, in so doing, butting up against the stop provided to prevent this. Complete the reassembly of the cells by burning the connectors together, as detailed under the head of Lead Burning.

Renewals. In many cases it will be found necessary upon overhauling a battery to renew the elements. These may be purchased either as loose plates or as groups ready to assemble in the battery. Except in garages doing a large amount of this work, it will not be advisable to buy the loose plates and burn them into groups.

The new groups should be assembled with rubber sheets and wood separators, as directed in overhauling the battery, the jars filled with fresh electrolyte of the proper specific gravity and the battery given a test charge and discharge with temporary connections. The electrolyte should be of 1.250 specific gravity, or seven parts of water to two of pure sulphuric acid by volume. If the test charge has been carried to a point where the specific gravity has ceased to rise for several hours, and the discharge shows no defectively assembled cells, the cells may be permanently connected.

Lead Burning. *Type of Outfit.* In the manufacture of storage batteries, and in garages where a large number of batteries are

Fig. 468. Arc-Welding Outfit for Burning Connections

maintained, a hydrogen-gas apparatus is employed for this purpose. For the electric-car owner or the garage doing a comparatively small amount of battery repair work, the Electric Storage Battery Company has placed an arc lead-burning outfit on the market. This is low in first cost and, with a little practice, good results can be obtained with it. As the battery itself supplies the power necessary, the only material required is the lead in the form of a flexible strip or heavy wire. The complete outfit is illustrated in Fig. 468. At one end is the clamp for making electrical connection, while at the other is a clamp of different form having an insulated handle and holding a one-fourth inch carbon rod. The two are electrically

connected by a flexible cable. This simple outfit can be employed in two ways, the second being preferable for the beginner, at least until sufficient amount of skill has been acquired to use the arc without danger of melting the straps.

First Method of Burning. In the first method, a potential of from 28 to 30 volts (12 to 15 cells) is required. The clamp should, therefore, be fastened to the positive pole of the twelfth to the fifteenth cell away from the joint to be burned, counting toward the negative terminal of the battery. The carbon then forms the negative terminal of the circuit. Otherwise particles of carbon will be carried into the joint, as the carbon rod quickly disintegrates when it forms the positive pole. The carbon should project 3 or 4 inches from the holder. The surfaces of the parts to be burned should be scraped clean and bright, and small pieces of clean lead about $\frac{1}{4}$ to $\frac{1}{2}$ inch square provided for filling the joint. The carbon is then touched to the strap to be burned and immediately withdrawn, forming an electric arc which melts the lead very rapidly. By moving the carbon back and forth the arc is made to travel over the joint as desired, the small pieces of lead being dropped in to fill the gap as required. Owing to the high temperature generated, the work must be carried out very quickly, otherwise the whole strap is liable to melt and run.

As this method is difficult and requires practice to secure good results, the beginner should try his hand on some scrap pieces of lead before attempting to operate on a cell. Its advantages are that when properly carried out it takes but a short time to do the work, and the result is a neat and workmanlike joint. It is extremely hard on the eyes, however, and should never be attempted without wearing smoked or colored glasses, and even with this protection the eyes should be directed away from the work as much as possible.

Second Method of Burning. The second method, utilizing the hot point of the carbon rod instead of the arc, is recommended for general practice. Scrape the parts to be joined and connect the clamp between the third and fourth cells from the joint. With this method it is not necessary to determine the polarity of the carbon. The latter is simply touched to the joint and held there; on account of the heavy flow of current it rapidly becomes red and then white hot. By moving it around and always keeping it in contact with the metal, the joint can be puddled. To supply lead to fill the joint,

an ordinary lead-burning strip can be used, simply introducing the end into the puddle of molten lead, touching the hot carbon. The carbon projecting out of the holder should be only one inch, or even less, in length. After the joint has been made, it can be smoothed off by running the carbon over it a second time.

Use of Forms to Cover Joint. In joining a strap which has been cut in the center, it is best to make a form around the strap by means of a piece of asbestos sheeting soaked in water and fastened around the strap in the shape of a cup, which will prevent the lead from running down. It will be found that sheet asbestos paper is thick enough, but it should be fairly wet when applied. By this means a neat joint can be easily made. The asbestos will adhere very tightly to the metal owing to the heat, but can be removed by wetting it again. When burning a pillar post to a strap, a form may be made around the end of the strap in the same manner, though this is not necessary if reasonable care is used. Two or three pieces of $\frac{1}{16}$-inch strap iron about one inch wide, and some iron nuts about one inch square are also of service in making the joint, the strap iron to be used under the joints, and the nuts at the side or ends to confine the molten lead. Clay can also be used in place of asbestos, wetting it to a stiff paste. As the holder is liable to become so hot from constant use as to damage the insulation, besides making it uncomfortable to hold, a pail of water should be handy, and the carbon dipped into it from time to time. This will not affect its operation in any way, as the carbon becomes hot again immediately the current passes through it.

Illuminating Gas Outfit. Heretofore it has not been possible to do good work in lead burning with illuminating gas, but a special type of burner has recently been perfected by the Electric Storage Battery Company, which permits the use of illuminating gas with satisfactory results. The outfit consists of a special burning tip and mixing valve. Sufficient $\frac{5}{16}$-inch rubber hose should be provided, and the rubber should be wired firmly to the corrugated connections, Fig. 469, as the air is used at a comparatively high pressure. A supply of compressed air is necessary, the proper pressure ranging from 5 to 10 pounds, depending upon the length of hose and the size of the parts to be burned. When air from a compressor used for pumping tires is utilized for this purpose, a suitable reducing valve must be introduced

in the supply line. This outfit is designed for use with ordinary illuminating gas and cannot be employed with natural gas.

Connect the air hose to the right-hand cock and the gas hose to the left-hand cock. The leader hose, about five or six feet long, is connected to the lower pipe and to the upper end of the burning tip. When the air pressure at the source is properly adjusted, close the air cock and turn the gas cock on full. Light the gas at the tip and turn on the air. If the flame blows out, reduce the air pressure, preferably at the source. With the gas turned on full, the flame

Fig. 469. Lead-Burning Outfit for Use with Illuminating Gas
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

will have a ragged appearance and show a waist about $\frac{1}{2}$ inch from the end of the tip, the flame converging there and spreading out beyond. Such a flame is not for lead burning.

Slowly turn the gas off until the outer portion at the waist breaks and spreads with an inner tongue of flame issuing through the outer ring. The flame will now have a greenish color and is properly adjusted for burning. If the gas is turned off further or if too much

air is turned on, the flame assumes a blue color gradually becoming invisible and is then deficient in heating power. When properly adjusted, the hottest part of the flame is just past the end of the inner point. Do not hold the flame too close to the work when burning, as its heating effect is greatly reduced and the flame is spread so as to make control difficult. The burning tip has at its lower end an outer sleeve and lock nut; this sleeve can be taken off in case any of the holes in the tip become clogged. The position of this sleeve is adjustable, the best position varying with the pressure of the flame, and it should be determined by experiment.

Hydrogen Gas Outfit. Hydrogen gas gives a hotter flame and therefore permits of more rapid work, so that where burning is done on a large scale, it is still preferred. The essentials of such an outfit are: first, a hydrogen generator; second, a method of producing air pressure at approximately 2 pounds to the square inch; and third, the usual pipe and tips for burning. If hydrogen gas is purchased in a tank and compressed air is available, only the blowpipe, tips, and a reducing valve on the air line are necessary. This is an expensive method to purchase hydrogen, however, so that it is usually generated, and a water bottle is needed between the generator and the blowpipe to wash the gas and to prevent the flame from traveling back to the generator.

For this purpose hydrogen gas is generated by placing zinc in a sulphuric-acid solution. The generator usually employed for vehicle-battery burning requires 50 pounds of zinc, 2 gallons of sulphuric acid, and 9 gallons of water for a charge. Where no compressed-air supply is available, an air pump and an air tank for equalizing the pressure must be used. An outfit of this kind is shown in Fig. 470. In preparing the generator for use, connect up as shown in this cut, taking care that the hose from the generator is connected to the nipple of the water bottle *L*. Have the water bottle one-half to two-thirds full and immerse it in a pail of cold water up to its neck. Replace the water in the pail whenever it becomes warm. Have stop cock *N* closed. Put the required amount of zinc, which has been broken into pieces small enough to pass through the opening *C*, into the lower reservoir. Put on cap *X* and screw down with clamp *D*, being sure that the rubber drainage stopper *H* is well secured in place. Pour the proper amount of water into reservoir *A* and then

pour in the acid, taking care to avoid splashing. *Always pour the water in first.*

In running the hose from *K* to *N*, arrange it so that there will be no low points for the water of condensation to collect in; in other words, this hose should drain back at every point to the water bottle. If, however, water should collect in the hose to such an extent as to interfere with the flame and it cannot readily be drained off, kink the hose between *T* and *U* and detach it from *K;* close the stop cock at *W* and pump until a strong pressure is obtained in the tank; then close

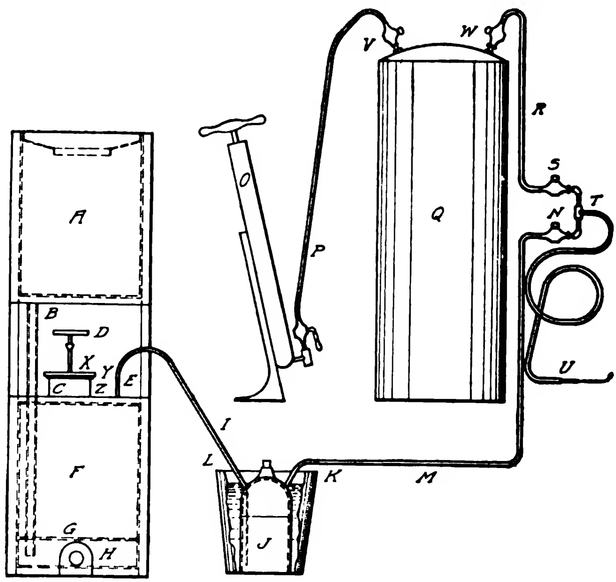


Fig. 470. Diagram of Lead-Burning Outfit, Using Hydrogen Gas

the cock at *V*, opening those at *S* and *N* and, finally, quickly open *W;* the pressure in the air tank will then force the water out of the hose. The length of the hose from *T* to *U* should be such that the mixing cocks at *S* and *N* are always within easy reach of the man handling the flame

In preparing the flame for burning, close the air cock at *S* and open *N* wide, hold a match to the gas until it lights, then add air and adjust the gas cock slowly, turning toward the closed position until the flame, when tried on a piece of lead, melts the metal and leaves a clean surface. The tip to be used depends on the work, but most vehicle-battery work is done with the medium tip. Replenish

the zinc every few days, keeping it up to the required amount. When a charge is exhausted or the generator is to be laid up for the night, the old solution should be drawn off before making up a new charge and the generator thoroughly flushed out by running water through *A*. The new charge should not be put in until the generator is to be used again. To empty the generator, first pull off the hose at the nipple *K*, then at *E*, and finally the rubber plug at *H*. Care should be taken not to allow the solution to splash on anything and not to dump the generator where the contents will damage cement, asphalt, or wood walks.

Installing New Battery. In not a few instances, it will be necessary to renew the entire battery. As received from the manufacturer, the battery is in a charged condition, i.e., it was fully charged just previous to being shipped, but it must be inspected and tested before being installed on the car. Care must be taken in unpacking it to avoid spilling any of the electrolyte. After cleaning off the packing from the tops of the cells, take out the rubber plugs and see that the electrolyte is ½ inch over the plates. If it is uniformly or approximately below the proper level in all the cells, this is simply the loss due to evaporation. But if low in only one or two cells, this is evidently caused by loss of electrolyte. In case this loss has resulted from the case being turned over in shipment, it will be indicated by the presence of acid on the packing on top of the battery (the acid does not evaporate), and some of the electrolyte will have been lost from all the cells. Replace the amount lost by refilling the cells with electrolyte of 1.250 specific gravity, as already directed.

In case the loss of electrolyte is caused by a cracked or broken jar, the packing under the battery will be wet. Replace the broken jar as instructed in the directions under that heading and add sufficient electrolyte of 1.250 specific gravity to make up for the loss. Should it be found, after replacing the broken jar and giving the battery an equalizing charge, that the specific gravity does not reach approximately 1.275, it is due to not having replaced the same amount of acid as was spilled. To adjust this, draw off the electrolyte from the cell with the syringe and add water or 1.300 acid to bring the specific gravity to between 1.270 and 1.280.

Storing a Battery. There is an amusingly erroneous idea prevalent to some extent that the charge of a storage battery is

represented by its electrolyte; that pouring off the electrolyte takes takes the charge with it; that, in case it is desired to store a battery, all that is necessary is to pour off the electrolyte and store the empty battery and the solution separately; and when it is desired to put the battery back in commission, it is then only necessary to pour the electrolyte back into the cells and, presto! they are ready to start the engine right away. Unfortunately for this theory, the charge is in the active material of the plates and not in the electrolyte.

It is frequently necessary to allow the battery to remain idle for a considerable length of time, in which case it should be put out of commission. If the battery itself is in good condition at the time and if it may be wanted for service again at short notice, this need only consist of giving it a long equalizing charge until the specific gravity has ceased to rise for several hours, then filling the cells to the top with distilled water and putting the battery away in a handy place. It should be given a freshening charge every two weeks or, at least, as often as once a month. If it is actually to be stored, there are two ways of doing this.

One is known as the wet storage method, and the other as the dry, the one to be adopted depending upon the condition of the battery and the length of time it is to be out of commission. The wet storage method is usually applied to any battery that is to be out of commission less than a year, provided that it will not soon require repairs necessitating dismantling it. The dry storage method is used for any battery that is to be out of commission for more than a year, regardless of its condition, and it is also applied to any battery that will shortly require repairs necessitating its dismantling. It will be apparent that this last-named class includes most starter batteries after they have seen several months of service, so that the majority can be placed in dry storage when necessary to put them out of commission.

Examine the conditions of the plates and the separators and also the amount of sediment in the bottom of the jars. If it is found that there is very little sediment and the plates and separators are in sufficiently good condition to give considerable additional service, the battery may be put into wet storage by giving it an equalizing charge and covering it to exclude dust. Replace evaporation periodically to maintain the level of the electrolyte ½ inch above the

tops of the plates. At least once every four months, charge the battery at one-half its normal finishing rate (see name plate on battery box) until all the cells have gassed continuously for at least three hours. Any cells not gassing should be examined, and the trouble remedied.

When examination shows that the battery will soon require dismantling, it should be put into dry storage. Dismantle the cells in accordance with the instructions already given. If the positive plates show much wear, they should be scrapped; if not, remove any loose particles adhering to them by passing a smooth wood paddle over the surface, but *do not wash the positive plates.* Charged negative plates will become hot in a short time when exposed to the air. They should be allowed to stand in the air until cooled.

Empty all the electrolyte out of the jars into a glass or glazed earthenware jar or a lead-lined tank and save it for giving the negative plates their final treatment before storage. Wash all the sediment out of the jars and wash the rubber separators carefully, then dry them and tie them in bundles. Place the positive groups together in pairs, put them in the jars, and store them away. Then put the negative groups together in the same way, place them in the remaining jars, and cover them with the electrolyte saved for the purpose, allowing them to stand in it for five hours, at least. Then pour off the electrolyte, which may now be discarded, and store away the jars containing the negatives. If the negative plates show any bulging of the active material, they should be subjected to the pressing treatment first, using boards and a vise, as described in a previous section. All of the jars should be well covered to exclude dust.

Make a memorandum of the amount of material required to reassemble the battery, and, when ordering this, provide for extra jars and covers, extra rubber separators, and an entire lot of wood separators with a sufficient excess to take care of breakage in handling. Unless the old connectors were carefully removed, order a new set. When a battery is put in storage, it is well to advise the owner in regard to the material necessary to reassemble, and to request at least a month's notice to procure it.

Charging from Outside Source. Theoretically at least, the starter battery on the automobile should be kept in an ideal condition. It is constantly under charge while the car is running at anything

except the lowest starting speeds and should accordingly always be fully charged. The generator is designed to take care of the storage battery and usually has sufficient capacity to light all the lamps in addition. Practice, however, does not bear out the theoretical view of the favorable conditions under which the starter battery is supposed to operate. It will be apparent at the very outset that the method of charging and discharging is not beneficial. To insure long life to a storage battery, it should be fully charged and then discharged to at least seventy-five per cent of its maximum capacity before recharging. It should never be allowed to stand discharged for any length of time. If exhausted, it should be recharged immediately. It should not be charged to half its capacity and then discharged. It should not be overcharged to the point where it continues to gas violently nor where its temperature exceeds 100° F.

All of these are things that should not be done to the storage battery, but it will take only a little experience to enable the garage man to recognize that all these are things which are constantly being done to the majority of storage batteries on gasoline automobiles. Most batteries receive treatment that reaches one extreme or the other, though it will be apparent that the middle course is almost as injurious to the battery. Either a battery is constantly kept undercharged so that it has insufficient charge to spin the engine more than once, and its operation is accordingly unsatisfactory, or it is constantly kept overcharged with the result that the hot acid makes comparatively short work of the plates, and they must be renewed in considerably less than a year of service. The mean course between these two is found in the case of the battery that is only charged to about half its capacity before being discharged again by the use of the starting motor. This treatment results in sulphating.

To keep the storage battery of the starting system in anything like efficient operating condition, it cannot be left on the running board with nothing but the generator of the starting and lighting system to charge it. Hydrometer and voltage tests will be valueless unless the conditions they indicate are remedied, and this cannot be done with the car generator as the sole source of charging current. Here is a typical instance: The battery is in good condition and it is fully charged. On a cold morning, it is drawn on intermittently

or almost fifteen minutes by the starting motor before the engine ires. As a result, it is practically discharged. The car is driven only a few miles, stopped and after a rest started again. What charge the battery received by the short run is again lost. The car is run for a little longer time and returned to the garage. The battery has received about one-fourth its normal charge. It stands this way for several days.

The weather being warmer, the engine starts in a much shorter time, but not before the starting motor has exhausted the small amount of charge in the battery. It is not run enough that day to charge the battery nor when taken out again that night, as all the lights are switched on, and under such conditions the battery receives very little current. Multiply this treatment by five or ten representing the number of days the car is driven during the month. At the end of that time, the battery no longer has sufficient charge to operate the starting motor at all and is condemned, as usual, by the car owner as being worthless. This is only one instance of many that are so similar that a few changes in detail would cover them all. No battery ever made could possibly operate efficiently under such conditions. After the car in question had been used a few days, a hydrometer test of the battery would have indicated its need of charging.

Equalizing Charges Necessary. Even where a battery receives almost 100 per cent of its normal charge before being discharged again, there will be numerous occasions on which the charge is not carried to completion. As mentioned under the head of Sulphating, that means so much acid left in the plates at the end of the charge. That acid represents lead sulphate which continues to increase in quantity as long as the acid remains in contact with the active material. To drive it out of the active material into the electrolyte, which is the function of charging, the charge must be carried to completion. This is termed an equalizing charge, and it should be given not oftener than once in two weeks, but at least once a month. To do this, it is necessary to charge the battery from an outside source, as it is seldom convenient to run the engine for the long period of time needed to complete such a charge. Except in cases where the battery is chronically overcharged, as indicated by its violent and continued gassing, it will usually be found necessary

to give it an equalizing charge once a month. The constantly overcharged condition is quite as injurious as its opposite, and it can be cured only by cutting down the output of the generator or increasing the demand upon the battery for current.

Methods of Charging. The apparatus employed for charging starter batteries will naturally vary in accordance with the number that are looked after in the garage. It may range from the makeshift consisting of a bank of lamps up to an elaborate panel board designed to provide charging connections for a dozen or more batteries at once. Where direct current is available—and only a few starter batteries need this attention—a bank of lamps in connection with a fused double-pole switch will be found to fill all the requirements. Note the charging rate (finishing) given on the name plate of the battery and make the number of lamps in accordance. A 32 c.p. in the circuit is practically the equivalent of one ampere of current entering the battery, i.e., it requires one ampere to light a lamp of this size and type (carbon filament) to incandescence. A number of standard lamp sockets should be mounted on a board, connected in multiple, and the group connected in series with the switch and the battery. (See illustration in résumé of questions and answers on the battery.) As many lamps as necessary may then be screwed into the sockets. The more current needed, the more lamps and the higher power lamps will be necessary. Tungsten lamps may be employed as well as the carbon-filament type, but as they take so much less current, lamps of higher candle power will be needed. For example, to replace a 32-c.p. carbon-filament lamp, a 100-watt tungsten lamp will be required.

Charging in Series for Economy. Where several starter batteries are to be charged at the same time, it will be found more economical to connect them in series and charge them all at once. The difference between the 110-volt potential of the lighting mains and the 6 to 8 volts needed to charge a single three-cell battery represents that much waste, as the drop in voltage has to be dissipated, through a resistance, to no purpose. In this way, any number of 6-volt storage batteries, up to twelve, can be charged from a 110-volt circuit (direct-current) with the same expenditure of current as would be required for a single battery. This is owing to the fact that, in any storage battery, the capacity of the battery is the capacity of one cell,

where all are connected in series. Consequently, it will take 10 to 15 amperes to charge one 6-volt battery from the lighting circuit, and when several more units of the same size are connected in series with it, the current consumption will still be the same, but a smaller part of the voltage will have to be wasted through a resistance.

Motor-Generator. Direct current will be found available in comparatively few places to-day, so that some means of rectifying an alternating current, in order to use it for charging batteries, will be necessary. Where quite a number of batteries are to be cared for, the motor-generator will be found to give the highest efficiency, besides proving more economical in other ways. As its name indicates, it consists of a motor wound for alternating current and fed from the supply mains of the garage, and a direct-current generator which is driven at its normal generating speed by the a.c. motor. There is no electrical connection between the two units. Electrical power in the form of an alternating current is converted into mechanical power in the a.c. motor which drives the armature of the d.c. generator and again converts it into electrical power in the form of a direct current. The first cost of a motor-generator is such that its use is usually confined to large establishments handling quite a number of batteries, though motor generators are now made in much smaller sizes than formerly.

A.C. Rectifiers. Where the amount of charging to be done does not warrant the investment in a motor-generator, a rectifier is usually employed. There are several makes of different types on the market: the chemical type, which employs lead and aluminum plates in an acid solution; the mercury-arc type, in which mercury is vaporized in a vacuum by the passage of the current; and others, in all of which the principle is the same. This consists in utilizing the current on but one part of the wave, so that the efficiency of these rectifiers ranges from 60 to 75 per cent. It is accordingly not good practice to employ them except in the smaller sizes. While the mercury-vapor rectifier is made for charging private vehicle batteries, the other types are ordinarily confined to sizes intended for charging small batteries.

A recent addition to the list that is available for this purpose is the Tungar rectifier, made by the General Electric Company. The principle on which this works is the same, but the medium is a new

one. This is a bulb exhausted of air and filled with a special gas in which a heavy tungsten-wire filament is brought to incandescence by the passage of the alternating current. This filament is very short and thick, its diameter depending upon the capacity of the rectifier, and it is placed horizontally. It constitutes the cathode of the couple. Directly opposite it, but a short distance away, is the anode of graphite in the form of a button, the lower face of which is presented to the tungsten wire. It is made in three sizes, the smallest of which has a capacity of but 2 amperes and is designed for charging the batteries of small portable lamps, such as are used by miners; and for charging ignition, call bell, burglar alarm batteries, and the like.

Fig. 471. Front View of Large Size G. E. Tungar Rectifier

In the larger size, as shown in Fig. 471, the bulb is mounted in an iron case, on the face of which are mounted the switch for alternating current; an ammeter on the d.c. side, showing the charge received by the battery; and a dial switch for adjusting the voltage to the number of batteries to be charged. There is a compensator with 15 taps, and the current is adjustable by steps up to 6 amperes. Anything from a single three-cell battery up to ten of such units

Fig. 472. Interior View of Small Size G. E. Tungar Rectifier
Courtesy of General Electric Company, Schenectady, New York

(30 cells in all) may be charged at once. The batteries must be connected in series and then it is only necessary to turn the switch of the a.c. circuit. In case the alternating-current supply should fail, the battery cannot discharge through the rectifier, and the latter

will assume its task again automatically as soon as the current comes on. This is the 6-ampere 75-volt size. It is also made in a 6-ampere 15-volt size designed for the charging of a three- or six-cell starter battery in the home garage. Fig. 472 shows an interior view of this size, illustrating the position of the converting bulb, the compensator, the reactance coil, and the fuses, while Fig. 473 illustrates the 6-ampere 75-volt size, showing the panel instrument, i.e., switch, ammeter, and regulating handle, as well as the bulb and fuses. A closer view of the bulb itself is shown in Fig. 474.

Fig. 473. Interior View of Large Size G.E. Tungar Rectifier

Care of Battery in Winter. There is a more or less general impression that special treatment must be given the storage battery during cold weather. This is probably owing to the fact that lack of attention makes itself apparent much more readily in winter than in summer because of the lower efficiency of the battery resulting from the lower temperature. The care necessary in winter does not vary in any respect from that which should be given in warm weather, except possibly that replacement of the water due to evaporation is not called for so often, but unless it is conscientiously carried out, the battery is apt to suffer to a greater extent. In speaking of low temperatures, it must be borne in mind that this always refers to the temperature of the electrolyte of the battery, and not to that of the surrounding atmosphere. The latter may be considerably below freezing, whereas the liquid in the cells may be approaching 100° F. when the battery is under charge.

Fig. 474. Tungar Rectifying Bulb—the Heart of the Rectifier

Make the usual hydrometer and voltage tests, as described under the headings in question, and see that the battery is constantly kept more fully charged than would be necessary to render satisfactory service in warmer weather. This is important for two reasons: first, because of the greatly increased drain on the battery owing to the difficulty of starting the engine when cold; and second, because of the liability of the electrolyte to freeze if the battery is allowed to stand discharged in very cold weather. There is not the same excess supply of current available for charging the battery in winter as there is in summer, as the lights are in use during a much greater part of the time and not so much driving is likely to be done during the day. As the lamp load consumes almost the entire output of the generator in the average starting and lighting system, there is very little left for the battery when all the lamps are in use. The practice of turning on all the lights on the car—headlights, side lights spot light, and instrument lights—whether they are necessary or not, should be discouraged in winter, as it is likely to result in exhausting the battery. The instrument lights are usually in series with the tail light, and so cannot be dispensed with, but it is never necessary to have the headlights and side lights going at the same time, and this also applies to the spot light, which consumes almost as much current as one of the headlights and should be restricted to the use for which it is intended, i.e., reading signs by the roadside.

Unless the lamp load is reduced, it may be necessary to increase the charging rate of the generator during the cold months, and this is not beneficial to the battery, as it may cause severe gassing and injury to the plates when continued too long. In case the car is not driven enough to keep the battery properly charged, it may be necessary to charge it from an outside source or, if the latter be not available, to run the engine with the car idle just for this purpose. Care must be taken to prevent any danger of freezing, and the best method of doing this is to keep the battery fully charged, as when in this condition it will freeze only at very low temperatures. The more nearly discharged a battery is, the higher the temperature at which it will freeze, and freezing will ruin the cells, regardless of whether it happens to crack the jars or not.

Why Starting Is Harder in Cold Weather. The electric starting and lighting system, or rather the storage battery, which is its main-

stay, is much more severely taxed in winter than in summer for the following four reasons:

(1) The efficiency of the storage battery decreases with a decrease in temperature, because the action of the storage battery is chemical, and chemical action is dependent upon heat and, therefore, always decreases as the temperature decreases.

(2) The lower the temperature the stiffer the lubricating oil, which gums the moving parts together, adding a very considerable load to the ordinary amount of inertia which the starting motor must overcome and likewise adding to the difficulty of turning the engine past compression.

(3) Gasoline will not vaporize readily at a low temperature, so that it is necessary to turn the engine over a great many revolutions before the cylinders become sufficiently warmed from the friction and the repeated compression to create an explosive mixture. The better the mixture the more readily it will fire, and consequently a greater heat value is required in the spark to ignite it where the mixture is poor or only partly vaporized. Anything that reduces the efficiency of the storage battery likewise reduces the heat value of the ignition spark.

(4) Low heat value of the spark often makes it difficult to start an engine when cold. This lack of heat in the spark is caused by a partially discharged battery as well as the lower efficiency of the battery caused by the cold weather; also by the necessity for repeated operation of the starting motor, whereby the voltage of the battery is temporarily cut down.

Intermittent use of the starting motor with a brief period between attempts will frequently result in starting a cold engine where continued operation of the starting motor will only result in exhausting the battery to no purpose. The longer the starting motor is operated continuously the lower the voltage of the battery becomes, with a corresponding drop in the heat value of the ignition spark. Cranking intermittently a number of times has practically as great an effect in warming the cylinders and generating an explosive mixture as running for the same period (actual operating time in each case), while the brief periods of rest permit the battery to restore its normal voltage, which increases the heat value of the spark and causes the engine to fire. Both the storage battery and the remaining essentials

of the starting and lighting system are designed to give satisfactory service in cold weather, but as a very low temperature brings about conditions representing the maximum for which the system is designed, more skillful handling is necessary in winter than in summer to obtain equally good results.

To Test Rate of Discharge. If the battery terminals are removable, take off either the positive or the negative terminal, and connect the shunt of the ammeter to the terminal post and to the cable which has been removed, binding or wiring it tightly in place to insure good contact. Where the battery terminals are not easily removable, insert the shunt in the first joint in the line,

Fig. 475. Setup for Testing Rate of Discharge of Small Storage Battery
Courtesy of Prest-O-Lite Company, Indianapolis, Indiana

as shown in the illustration, Fig. 475. Then connect the ammeter terminals to the shunt. In case the instrument shows a reverse reading, reverse the connections to the shunt. When the ammeter is connected to test for discharge, the starter must never be used unless the 300-ampere shunt is in circuit, as otherwise the instrument is likely to be damaged. If a shunt of smaller capacity or a self-contained ammeter, i.e., one designed to be connected directly in the line is employed, and it is necessary to start the engine, either crank by hand or disconnect the ammeter before using the starting motor.

When the ammeter is connected to show the discharge and no lights are on, the engine being idle, no current is being used for any purpose, and the pointer of the ammeter should remain at zero. If any flow of current (discharge) is indicated, it shows that there is a ground or a short-circuit (a leak) somewhere in the system. In such a case, apply the usual tests described under the appropriate headings for locating grounds and short-circuits.

With the ammeter connected up as shown in the illustration, the discharge rate of the battery under the various loads it is called upon to carry may be checked up, and, if it proves to be excessive in any case, the trouble may be remedied. For example, with the 300-ampere shunt in the line, the amount of energy consumed by the starting motor may be checked. Without knowing how much current a certain make of starting motor should consume in turning over a given type of engine, it will naturally be impossible to make any intelligent comparisons with the result of the tests. This information, however, is readily obtainable from the manufacturer of the starting system, and it will be found advantageous to obtain details of this nature covering the various systems in general use in your locality, as it will enable you to make these tests valuable in correcting faults. While the starting loads imposed on the electric motor by different engines will vary greatly, the general nature of the load will be practically the same in all cases. When the starter switch is closed, there will be an excessive discharge rate from the battery for a few seconds, the discharge falling off very rapidly as the inertia of the engine is overcome and it begins to turn over, with a still greater drop to a comparatively small discharge the moment it takes up its cycle and begins to run under its own power.

Before undertaking such tests, see that the battery is in good condition and fully charged. Make several tests. Note in each case whether the maximum discharge at the moment of closing the switch exceeds the maximum called for by the maker of the starting system. If a great deal more current is necessary to turn the engine over than should be the case, it is an indication either that the starting motor is in need of attention or that the engine itself is unusually stiff. Atmospheric conditions will naturally have a decided effect on the result of such tests, as an engine that has stood overnight in a cold garage will be gummed up with thick lubricating oil and

will require more power to move it at first than if it had been running only a few minutes before. As a general rule, more power will always be needed in winter than in summer, unless the tests are carried out in a well-heated garage. The condition of the engine itself will also have an important bearing on the significance of the tests, as, if the engine has been overhauled recently, its main bearings may have been tightened up to a point where the engine as a whole is very stiff.

Note also whether the discharge rate falls off as quickly as it should when the engine begins to turn over rapidly. If it does not, this also is an indication of tight bearings, gummed lubricating oil, or similar causes, rendering the engine harder to turn over. In the case of a cold engine, stiffness due to the lubricating oil may be remedied by running it for ten or fifteen minutes, and a subsequent test should then agree with the manufacturer's rating. Where the discharge rate does not drop to a nominal amperage within a few seconds from the time of closing the switch, it is simply an indication that the essentials of the engine are not in the best of working order. The carburetor may not be working properly, or the ignition may be sluggish.

In case the discharge rate is very much less than that called for by the manufacturer for that particular engine, it is an indication that the starting system itself is not in the best condition. Poor connections, worn brushes, loose brush springs, a dirty switch, or some similar cause is greatly increasing the resistance in the starting circuit, thus cutting down materially the amount of current that the battery can force through it. In such circumstances, the discharge may not reach so high a rate as that called for by the manufacturer, but to effect a start, even with the engine in normally good condition, a high rate will have to be continued longer, to the correspondingly greater detriment of the battery. In other words, a great deal more current must be drawn from the battery each time the engine is started. Thus, testing the rate of discharge may be made to serve as an indication of the condition of both the starting system and the engine itself. Should it be necessary to make more than eight or ten starts to determine definitely the cause of any variation between the discharge rates shown and those that should be indicated, with everything in normally good condition, the battery should be fully

recharged before proceeding any further, as using it for this purpose when almost exhausted is very likely to damage it. Tests of this kind show also whether the efficiency of the battery has fallen off substantially or not, as indicated by its condition after making several starts in succession. When this has been done, the battery may be tested with the voltmeter and hydrometer to ascertain how far it has been discharged. The fact that after having been in service for some time a starting system will not start the engine so many times without exhausting the battery as it would when new may be due either to a loss of efficiency in the battery or to the poor condition of the other essentials of the system. In the majority of cases, however, it will be due to the condition of the battery.

By substituting the 30-ampere shunt for the 300-ampere, the load put on the battery by the lights when switched on in various combinations may be checked and compared with the manufacturer's ratings. Where the discharge rate for the lights is less than it should be, it may be due to the use of bulbs which have seen a great deal of service, the resistance of the filaments increasing with age, or other causes which place more resistance in the circuit, such as poor connections, loose or dirty switches, and the like. Tests may also be made of the ignition system where the battery is called upon to supply current to a distributor and coil by putting the 3-ampere shunt in the circuit. The amount of current required by the ignition system is very small when everything is in normal working order, usually not more than 1½ to 2 amperes. This also can be obtained definitely from the maker of the apparatus. Any great increase in the amount of current necessary would usually indicate arcing at the contact points, which should prove to be in poor condition; a subnormal discharge would signify a great increase in the resistance as in the foregoing cases, and should be evidenced by poor ignition service.

To Test Rate of Charge. To determine the rate at which the battery is being charged (the small dash ammeters are only approximately accurate), reverse the ammeter connections and start the engine by hand. If the car is equipped with a straight 6- or 12-volt system and a dash ammeter is used, see that its reading agrees approximately with the portable ammeter. Should the variation be small, advise the owner so that he may correct his readings

accordingly when noting the instrument on the road. In case it is very large, the dash ammeter itself should be adjusted, which can frequently be done merely by bending the pointer.

With the engine running fast enough to give the maximum charging rate, which is indicated by the fact that the ammeter needle stops rising, check the charging rate shown on the portable ammeter, bearing the following in mind: In the majority of cars, the generator is regulated to charge the battery at from 10 to 15 amperes. Some are designed to charge at as low a rate as 7 amperes. Unless the proper charging rate is definitely known, whatever maximum the portable ammeter shows may usually be assumed to be correct. Where the rate is less than 7 amperes it may generally be taken for granted, however, that the battery is undercharging, and the various tests, described in detail under appropriate headings, may be applied to locate the trouble either in the generator or in the automatic cut-out. This applies where the charging rate is too high as well as where it is too low.

The charging rates mentioned above naturally apply only to a 6-volt battery, or to a battery having a greater number of cells, which is connected in series multiple so as to charge at 6 volts. In the case of a six-cell battery permanently connected in series so that it both charges and discharges at 12 volts, the above figures must be cut in half. Twelve-cell batteries are employed in some cases, but the total voltage of the battery is used only for starting, the cells being divided into four groups in series multiple so that each group of three cells charges at 6 volts.

With the generator charging at 10 to 15 amperes, turn on all the lights. If more current is being drawn from the battery than is being supplied by the generator, this will be indicated by the ammeter showing a reverse reading or discharge. It signifies that there is a short-circuit in the lighting switch or the lamps, or in the wiring between the switch and the lamps, or that additional lights, other than those furnished originally with the system, have been added, or larger candle-power bulbs substituted, thus placing too great a demand on the battery.

If the system has been out of adjustment for any length of time, it is quite likely that the battery will shortly need repairs or replacement, because charging at an excessive rate causes the plates

to buckle and break through the separators, forming an internal short-circuit, while charging at too low a rate causes a constantly discharged condition of the battery, due to more current being normally called for than is put in. This results in injurious sulphating of the plates.

In case additional equipment has been added, the entire equipment should be turned on, and the total current required should be noted when making discharge-rate tests. Where the generator cannot supply sufficient current to permit the battery to take care of this extra equipment, the battery should be charged from an outside source at regular intervals. It is poor practice to increase

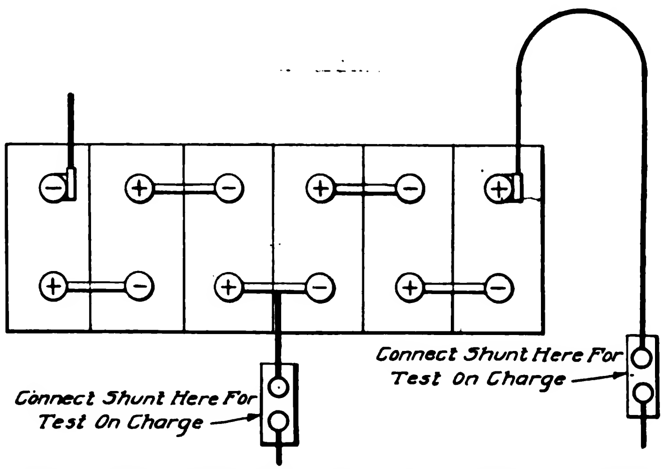


Fig. 476. Setup for Twelve-Volt Battery Wired to Charge and Discharge through Starting Motor at Twelve Volts and through Lamps at Six Volts

the charging rate of the generator, as it is likely to injure the battery through overheating. Where it is necessary to have a higher charging rate than that originally called for by the system, it is preferable to substitute a larger battery. The charging rate of the generator may then be safely increased in accordance with the demand.

In cold weather, it may be necessary to slightly increase the charging rate of the generator in order to compensate for the extra current the battery is called upon to supply. This is owing, not only to the fact that there is a much greater demand on the starting system in cold weather, but also to the fact that the battery is less efficient under winter conditions of operation.

Connections for Two-Voltage Batteries. Where the battery is of either three or six cells, all connected permanently in series, the foregoing suggestions for connecting the testing instruments apply. They must be varied, however, where tests are to be made of batteries connected in series multiple, which may be termed two-voltage batteries since they supply current at one voltage for lighting and at another for starting. In Fig. 476 is shown a battery of this type which is connected so as to charge and discharge through the starting motor at 12 volts, but which discharges at 6 volts to supply the lamps through a neutral lead in the center of the battery. The sketch indicates where to connect the ammeter shunt on charge at

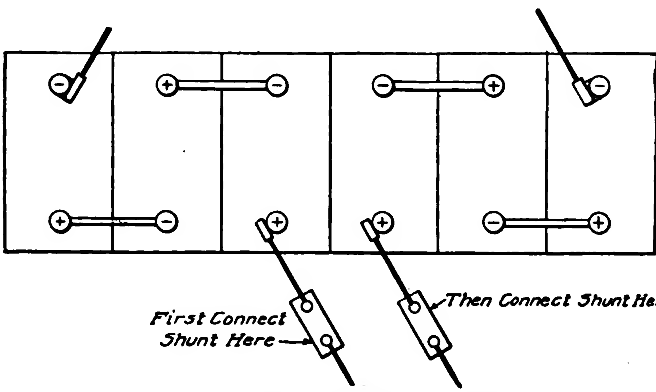


Fig. 477. Twelve-Volt Battery Connected Up to Make Two 6-Volt Batteries in Parallel

12 volts and on discharge at 6 volts. When testing the starting-motor discharge, it would be connected for 12 volts.

Test the 12-volt circuit with the engine running to get the charging rate; stop the engine, reverse the ammeter terminals and see whether there is any discharge indicating a short-circuit. Also test the discharge rate on the 6-volt circuit with the lights turned off and again with all lights on. These tests should show whether or not there is a short-circuit in the system. Before attempting to test the discharge rate of the starting motor, be certain that the 300-ampere shunt is in the circuit. A 12-volt battery will discharge only about half the current necessary to start the engine with a 6-volt battery, but no shunt smaller than the 300-ampere size can be depended upon to carry the load safely and protect the instrument.

Fig. 477 shows a 12-volt battery connected up in such a manner that it is practically two 6-volt batteries in parallel. The battery is charged at 6 volts, and both the lights and horn are supplied with current at this voltage, but the discharge through the starting motor is at 12 volts. Note the two positive cables leading to the center of the battery. To test the charging rate, the ammeter shunt should be connected first in one of these cables and then in the other, and the two readings added together to obtain the charging rate for the entire battery. The same locations for the shunt, and the same method of adding the readings also apply on discharge. Ammeter readings in the connections shown will indicate whether or not there are any short-circuits, except, of course, in the starting-motor cable.

Voltage Tests. An equally important instrument for the testing of the storage battery is the voltmeter. It is chiefly useful in showing whether a cell is short-circuited or otherwise in bad condition. Under some conditions, it indicates when the battery is practically discharged, but, like the hydrometer, it must not be relied upon alone. It should be used in conjunction with the hydrometer readings to insure accuracy. Since a variation as low as .1 (one-tenth) of a volt makes considerable difference in what the reading indicates as to the condition of the battery, it will be apparent that a cheap and inaccurate voltmeter is likely to be misleading rather than helpful. For garage use, a good reliable instrument with several connections for giving a variable range of readings should be employed. Instructions furnished with the instrument give in detail the method of using the various connections, and these instructions should be followed closely, as otherwise the voltmeter is likely to be damaged. For example, on the 3-volt scale only one cell should be tested. Attempting to test any more is likely to burn out the 3-volt coil in the meter. The total voltage of the number of cells tested must never exceed the reading of the particular scale being used at the time, as otherwise the instrument will be ruined.

Always make certain that the place on the connector selected for the contact of the testing point is clean and bright and that the contact is firm, as otherwise the reading will be misleading, since the increased resistance of a poor contact will cut down the voltage. The positive terminal of the voltmeter must be brought

in contact with the positive terminal of the battery, and the negative terminal of the voltmeter with the negative terminal of the battery. If the markings of the cell terminals are indistinct, the proper terminals may be determined by connecting the voltmeter across any one cell. Should the pointer not give any voltagė reading, butting up against the stop at the left instead, the connections are wrong and should be reversed; if the instrument shows a reading for one cell, the positive terminal of the voltmeter is in contact with the positive of the cell. This test can be made with a voltmeter without any risk of short-circuiting the cell, since the voltmeter is wound to a high resistance and will pass very little current. This is not the case with an ammeter,

Fig. 478. Proper Setup for Testing Voltage of Batteries

however, as connecting such an instrument directly across the terminals of the battery will immediately burn out the ammeter.

Inasmuch as any cell, when idle, will show approximately 2 volts, regardless of whether it is fully charged or not, voltage readings taken when the battery is on open circuit, i.e., neither charging nor discharging, are practically valueless, *except when a cell is out of order*. Therefore, a load, such as switching on the lamps, should be put on the battery before making voltage tests. With the lights on, connect the voltmeter as explained above and test the individual cells, Fig. 478 (Prest-O-Lite). If the battery is in good condition, the voltage readings after the load has been on for about five minutes will be but slightly lower (about one-tenth of a volt) than if the battery were on open circuit. If any of the cells are completely discharged,

the voltage of these cells will drop rapidly when the load is first put on and, sometimes when a cell is out of order, even show reverse readings. Where the battery is nearly discharged, the voltage of each cell will be considerably lower than if the battery were on open circuit after the load has been on for five minutes. In the case of an electric-vehicle battery, the lights alone would not provide sufficient load for making an accurate test, so that one of the rear wheels may be jacked up and the brake set lightly until the ammeter on the dash of the car shows 50 to 70 per cent of the usual normal reading. To do this, start the motor on first speed with the brakes loose, and apply the brakes slowly until the desired load is shown by the ammeter reading. Never, under any circumstances, attempt to start with the brakes locked or on hard, as both the battery and the motor will be damaged. In the case of a starting-system battery, the lights alone are sufficient load, as they consume about 10 amperes.

To distinguish the difference between cells that are merely discharged and those that are out of order, put the battery on charge (crank the engine by hand in the case of a starter battery) and test again with the voltmeter. If the voltage does not rise to approximately 2 volts per cell within a short time, it is evidence of internal trouble which can be remedied only by dismantling the cell.

Temperature Variations in Voltage. It must be considered, in making voltage tests, that the voltage of a cold battery rises slightly above normal on discharge. The reverse is true of a really warm battery in hot weather, i.e., it will be slightly less than normal on charge and higher than normal on discharge. As explained in connection with hydrometer tests of the electrolyte, the normal temperature of the electrolyte may be regarded as 70° F., but this refers only to the temperature of the liquid itself as shown by a battery thermometer, and not to the temperature of the surrounding air. For the purposes of simple tests for condition, voltage readings on discharge are preferable, as variations in readings on charge mean little except to one experienced in the handling of storage batteries.

Joint Hydrometer and Voltmeter Tests. In making any of the joint tests described below, it is important to take into consideration the following four points:

(1) The effect of temperature on both voltage and hydrometer readings.

(2) Voltage readings should only be taken with the battery discharging, the load being proportioned to the size of the battery, as voltage readings on an idle battery in good condition indicate little or nothing.

(3) In the case of a starter battery, never attempt to use the starting motor to supply a discharge load for the battery, because the discharge rate of the battery while the starter is being used is so heavy that even in a fully charged battery in good condition it will cause the voltage to drop rapidly.

(4) The voltage of the charging current will cause the voltage of a battery in good condition to rise to normal or above the moment it is placed on charge, so that readings taken under such conditions are not a good indication of the battery's condition.

In any battery which is in good condition, the voltage of each cell at a normally low discharge rate (20 to 30 amperes for a vehicle battery or 5 to 10 amperes for a starting-system battery) will remain between 2.1 and 1.9 volts per cell until it begins to approach the discharged condition. A voltage of less than 1.9 volts per cell indicates either that the battery is nearly discharged or that it is in bad condition. The same state is also indicated when the voltage drops rapidly after the load has been on a few minutes. The joint hydrometer and voltmeter tests given below will be found to cover the majority of cases met with in actual practice.

(1) A voltage of 2 to 2.2 per cell with a hydrometer reading of 1.275 to 1.300 indicates that the battery is fully charged and in good condition.

(2) A voltage reading of less than 1.9 per cell with a hydrometer reading of 1.200 or less indicates that the battery is almost completely discharged.

(3) A voltage of 1.9 or less per cell with a hydrometer reading or 1.220 or more indicates that excess acid has been added. Under these conditions, lights will burn dimly, although the hydrometer reading alone indicates the battery to be more than half charged.

(4) Regardless of voltage—high, low or normal—any hydrometer reading of over 1.300 indicates that an excessive amount of acid has been added.

(5) Where a low voltage reading is found, as mentioned in cases 2 and 3, to determine whether the battery is in bad order or

merely discharged, stop the discharge by switching off the load, and put the battery on charge (crank the engine by hand in the case of a starter battery) and note whether the voltage of each cell promptly rises to 2 volts or more. If not, the cell is probably short-circuited or otherwise in bad condition.*

Cleaning Repair Parts. The advent of electric starting and lighting systems has added appreciably to the amount of attention required by machines in the garage, particularly as this essential is a part of the car about which its owner generally knows little. In fact, it is not overstating it to say that fully 25 per cent of all the repair work now carried on in the garage has for its object the keeping

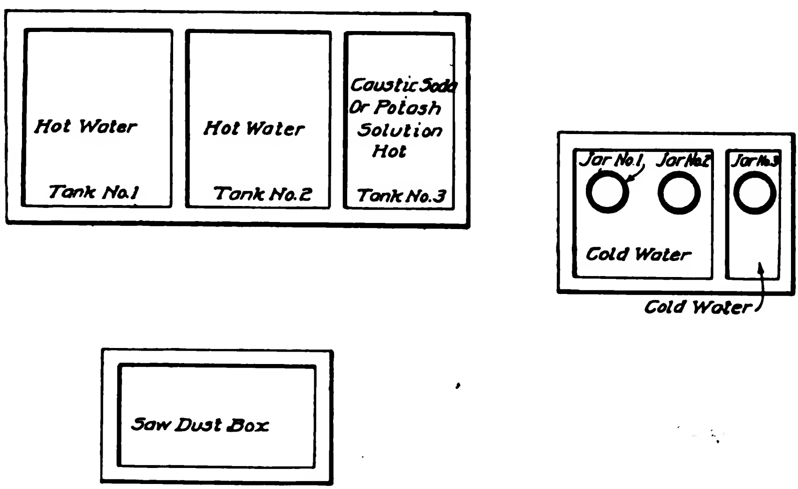


Fig. 479. Layout for Battery Cleaning Outfit

of the electrical equipment of the car in good operating condition. Where many cars are cared for and repairs to their electric systems are made as far as possible right in the garage, it will be found advisable to install a method for cleaning parts. Owing to the accumulations of dirt and grease that parts carry after having been in service for a year or more, cleaning them thoroughly before making any repairs makes it possible to detect defects which might otherwise pass unnoticed. The following instructions are reprinted through the courtesy of the makers of the Delco apparatus, and they strongly recommend that the solutions mentioned be used in the exact manner

* From instructions issued by the Prest-O-Lite Company, Indianapolis, Indiana.

directed, as they are the result of several years' experience in this work, and considerable care has been used in checking them. The sizes of the tanks given are merely indicative of what a very large repair shop would require and are comparative only. They will naturally vary with the amount of work to be done.

Cleaning Outfit. The cleaning outfit should consist of three sheet-steel tanks, Fig. 479, of suitable size (35 gallons for a large shop) mounted so that their contents may be kept heated to the desired temperature, three stone jars of approximately 15 gallons capacity, and a sawdust box. Two of the steel tanks should be equipped with overflow pipes so that they can be kept about two-thirds full at all times. These are tanks No. 1 and No. 2. They are used for clear hot water for rinsing parts after they have been cleaned. The third tank does not require a drain nor an overflow pipe and is used for the potash or caustic soda solution. This can be used for a long time without changing by simply adding a small amount of soda as the solution weakens. All three tanks are maintained at a temperature of 180° to 212° F., or approximately the boiling point.

The three jars mentioned are used for the acid solutions and are referred to as jars No. 1, No. 2, and No. 3. A wood tank large enough to hold the three jars and divided into two compartments, as shown in Fig. 479, should be provided. This is important, as the parts cannot be rinsed in the same cold water after being immersed in the different acid solutions. The solutions recommended are in tanks 1 and 2, clear hot water; tank 3, a solution consisting of one pound of caustic soda per gallon of water. Jar No. 1 is filled with a solution consisting of four gallons of nitric acid, one gallon of water, and six gallons of sulphuric acid. The water is placed in the jar first, the nitric acid is added slowly, and the sulphuric acid is poured in last. This order must be strictly followed, as it is dangerous to mix a solution of these acids in any other manner. In jar No. 2, the solution is one gallon of hydrochloric acid to three gallons of water, while jar No. 3 contains a solution of one-half pound of cyanide to a gallon of water. Tank No. 2 should be used only for parts which have been in the potash solution and for no other purpose. Tank No. 1 is for general rinsing purposes.

Method of Cleaning Parts. Various metals are cleaned as follows: Steel is boiled in the potash solution until the dirt is removed, which

should require only a few minutes. The steel part is then rinsed in tank No. 2 and dried in sawdust. Vast iron parts are boiled in the potash solution to remove dirt, rinsed in tank No. 2, dipped in the acid solution in jar No. 1, rinsed thoroughly in cold clear water, dipped in the cyanide solution, rinsed again in cold clear water, then rinsed in tank No. 1 and dried in sawdust. Copper can be cleaned in the same manner. Polished aluminum should first be thoroughly washed in gasoline, rinsed in tank No. 1, dipped in the acid solution in jar No. 1, rinsed thoroughly in cold clear water, rinsed in tank No. 1, and dried in sawdust. Plain aluminum, unpolished, should be dipped in the potash solution, rinsed in tank No. 2, dipped for a few seconds in the acid solution, rinsed in tank No. 2, dipped for a few seconds in the acid solution in Jar No. 1, rinsed in cold water, then rinsed in tank No. 1, and dried in sawdust.

It will be noticed that when aluminum is put into the potash solution the metal is attacked and eaten away rapidly, so that polished parts of this metal should not be put into this solution, and any aluminum parts should not be left in for a moment longer than necessary. Where the parts are covered with caked deposits of hard grease, they should first be washed in gasoline. Aluminum parts should never be put into the potash solution unless they can be put through the acid immediately after, as the acid dip neutralizes the effect of the potash solution. Parts should only be held in the acid for a few seconds. Paint should first be removed with a good paint or varnish remover unless it is present in very small quantity, and unless the aluminum parts are to go through the potash solution. Enameled work should be washed with soap and water, dried thoroughly, and then polished with a cloth dampened with a good oil, such as Three-in-One. These cleaning methods apply only to solid parts and should never be employed on any plated pieces, as the caustic and acid would immediately strip off the plating. Such parts can be cleaned only in gasoline. It will be apparent, however, that cleaning in this manner will be found advantageous for many parts of the car that have to be repaired other than those of the electric equipment, and, in view of the increasing cost of gasoline, will be found much more economical as well as much more thorough.

TYPICAL BOSCH-RUSHMORE STARTING MOTOR
Courtesy of Bosch Magneto Company, New York City

BOSCH MAGNETO INSTALLATION ON 1916 HUPMOBILE
Courtesy of Bosch Magneto Company, New York City

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART IX

ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

SUMMARY OF INSTRUCTIONS ON ELECTRIC STARTING AND LIGHTING

It will be apparent from the foregoing description of the various systems that while the majority differ more or less in detail all are based on a comparatively small number of well-defined principles, and that once these are mastered their application in any system under consideration will be clear. To avoid unnecessary duplication in the instructions covering points that are common to all, general instructions have been given only in connection with one or two systems, and it will be understood that descriptions of the methods of locating short-circuits or grounds, of caring for brushes and commutator, and of testing with a portable lamp or with the volt-ammeter are equally applicable to all. The instructions given with other systems accordingly are limited to special references to the details of installation that will make it easier to locate faults in that particular system.

In order to bring the two together in such form that the particular information desired may be found instantly, a summary of all the instructions given in the preceding sections is outlined here in questions and answers.

GENERATORS

Types and Requirements

Q. How many types of generators are used in starting and lighting service on the automobile?

A. Practically all are of one type, i.e., compound-wound, but this is subdivided into other types, such as differential compound-

wound, cumulative compound-wound, and the like, that is, all lighting generators have a shunt and a series winding on their fields, but the relation of these windings to one another differs, depending upon the characteristics of the remainder of the system.

Q. What is a differential compound-wound generator?

A. One in which the series winding is reversed, i.e., wound in a direction opposite to that of the shunt winding so that its exciting effect on the field magnets opposes that of the shunt winding. The series winding is then termed a bucking coil because it bucks, or opposes, the exciting effect of the shunt winding on the field magnets as the speed increases. The series winding in this case is used simply for regulating the generator output.

Q. What is a cumulative compound-wound generator?

A. One in which the exciting effect of the series coil is added to that of the shunt coil, the series coil in this case having no connection with the regulation of the generator output.

Q. As one of the chief requirements of an efficiently operating system is the control of the generator output under widely varying speeds, how is a generator of the cumulative compound-wound type employed on the automobile?

A. The series winding is in practically an independent circuit in connection with the lamps of the car so that its exciting effect is not added to the field magnets except when the lights are switched on. This automatically increases the generator output in accordance with the number of lights turned on so that the lights have no effect on the battery charging rate, which remains the same whether the lights are on or off. An external regulator is employed to control the battery-charging rate.

Q. How does the generator differ from the motor?

A. Its essentials are all the same, i.e., it has a wound armature revolving in a magnetic field, commutator, brushes, etc., exactly the same as the generator.

Q. This being the case, why are the two not interchangeable?

A. To a certain extent they are, that is, when a current is sent through the generator from an outside source, it becomes motorized and will run as a motor. But the two are far from being interchangeable on the automobile, owing to the widely differing requirements for which they are designed. The generator is wound to produce a cur-

rent seldom exceeding a value of 20 amperes while being driven over a wide range of speeds, and it is in constant operation. The starting motor, on the other hand, is designed to utilize an extremely heavy current, ranging up to 300 amperes or more at the moment of starting and is only used for very short periods.

Q. How are these widely varying requirements reconciled in the single-unit type, in which both the generator and the motor are combined in one machine?

A. The machine is practically two units in one, i.e., there are two totally different windings on the same magnet cores, a fine winding with shunt fields for the generator, and a very heavy simple series winding for the motor end. In some cases, as in the Delco, the different windings on the armature are brought out to independent commutators. While combined on one set of magnet cores, there is no connection whatever between the two windings in such a machine, so that when operating as a generator the motor windings are dead, and the reverse is true when being used as a starting motor.

Q. What are the characteristics of the single-unit type of machine which is simply placed in circuit with the battery by a hand-operated switch when starting and left in that relation as long as the engine is running?

A. This is a variable-potential type in which the relation that it bears to the battery and to the engine is entirely dependent upon the speed of the engine, that is, the speed at which the machine is driven. When the switch is closed, current from the battery operates the machine as a starting motor; as soon as the engine starts and attains a certain speed, the voltage of the machine overcomes that of the battery, the direction of current flow is reversed, and the battery begins to charge. Whenever the driving speed falls below a certain point, there is another reversal, and the generator once more becomes a motor until the engine speed increases.

Loss of Capacity

Q. What are the chief causes for the falling off in output of the generator?

A. In about the order of the frequency of their occurrence, these are as follows: dirty or worn commutator; worn brushes making poor contact; dirty or loose connections causing extra resistance

at generator, regulator, cut-out, ground, or battery terminals; failure of cut-out to operate at proper voltage; worn or pitted contacts in regulator or cut-out; loose connections at brush holders; short-circuited coils in the armature; some of the armature-coil connections broken away from the commutator; short-circuited bars in the commutator.

Q. How can the generator output be tested?

A. The simplest method is to switch on all the lamps with the engine idle. Start the engine and speed up to equivalent of 15 miles per hour. The lights should brighten very perceptibly, the test being made indoors in the daytime with the lights directed against a dark wall, or preferably at night. A more accurate test can be made with the portable volt-ammeter, using the 30-ampere shunt. Most generators have an average current output of 10 to 12 amperes, but the normal output as given by the maker should be checked before making the test. Generators having a constant-voltage control will show a greatly increased output if the battery charge is low, running up to 20 amperes or over. On such machines, the condition of the battery should be checked either with the hydrometer or with the voltmeter before making the test. The charging current should be 10 to 12 amperes with a fully charged battery, and more in proportion when only partly charged.

Q. What other simple method is there of determining quickly whether the generator is producing its normal output or not?

A. On generators having an accessibly located field fuse (there are several makes) lift this fuse out and, with the engine running at a speed equivalent to 10 miles per hour or more, touch the fuse terminals lightly to the clips. If the machine is generating properly, there will be a bright hot spark. Should no spark appear, replace the fuse and bridge the terminals with a pair of pliers by touching the jaws to the fuse clips; if a spark appears, the fuse has blown. Before replacing with a new fuse, find the short-circuit or other cause.

Q. Granting that the fuse has not blown, that the cut-out, regulator, and wiring are all in good condition, and still the generator does not produce any current, what is likely to be the cause?

A. One of the brushes may not be touching the commutator, a brush connection may have broken, or carbon dust may have short-circuited the armature or field windings. Test for short-circuits.

Q. If the machine is generating current, and the auxiliary devices and wiring are in good condition, but the battery does not charge, what is the cause?

A. Short-circuit in the battery due to active material having been forced out of the plates, or accumulation of sediment touching plates at their lower ends. (See Battery Instructions.)

Q. Is the regulator ever responsible for a falling off in the current or for generation of excessive current?

A. Yes. Any irregularity in the operation of the regulator will affect the output of the generator.

Q. How can this be overcome?

A. This will depend upon the type of regulation employed (see Regulation). Where the method of regulation is inherent, i.e., forming part of the construction of the generator itself, such as the third-brush method, or a bucking coil, it may be remedied by cleaning and seating the brush properly or by testing the bucking-coil winding to see if its connections are tight and clean, or if it is short-circuited (see Windings). If cleaning and sanding-in the brush do not cause the generator to produce its normal output, the brush itself may be adjusted by shifting its location. Moving it backward or against the direction of rotation of the commutator will reduce the output; moving it forward or in the direction of rotation will increase the output. This refers specifically to the Delco regulation already described. To adjust properly, the portable ammeter should be put in circuit, and the effect on the reading noted as the brush is moved, clamping it back in place when the proper point is found. The brush should then be sanded-in to the commutator, as it will not have a good bearing if its original location has been disturbed.

Methods of Regulation

Q. Why is it necessary to control the output of the generator?

A. As explained in the section on electric generators, the amount of current produced depends upon the excitation of the fields, and the faster the armature revolves before the pole faces of the field magnets, the greater the amount of current that is sent through the windings of the magnets. As the speed of the automobile engine varies between such extremely wide limits, it will readily be seen that

it may rise to a point where this increase in the field excitation will cause so much current to be generated that the armature windings will be literally burned up. This happened very frequently in the early attempts to produce a lighting dynamo for automobile service. Regardless of how fast the generator may be driven, it is essential that its current output does not exceed a certain safe limit.

Q. What is the usual safe limit in the majority of generators?

A. Most automobile lighting-system generators are designed to produce 10 to 15 amperes at a normal speed, i.e., sufficient to light all the lamps and still provide a slight excess for charging the battery. No matter how fast its armature revolves, it must not exceed this by more than ten to twenty-five per cent, as a rule, this being well within its factor of safety. In some instances, where a voltage system of regulation is employed, the output of the generator depends upon the condition of charge of the battery. If the battery is practically discharged, the generator will charge the battery at a rate of twenty amperes or over. As the charge proceeds, the battery voltage increases and the resistance is increased correspondingly, thus cutting down the amount of current that the generator can force into the battery.

Q. How is the current generated kept from exceeding this safe limit?

A. Mechanical methods were employed at first, a centrifugal governor being used to operate a slipping clutch. The generator was driven through this clutch, and the speed at which the armature revolved depended upon the engagement of the clutch; at low speeds both shafts would turn at the same rate. As the driving-shaft speed increased, the governor decreased the pressure on the clutch spring, and the clutch faces slipped on one another, so that the driven shaft turned proportionately slower than the driving shaft. The earliest types of governors, employed about 1903 to 1905, were not successful, but about 1908 a type was developed that worked effectively on thousands of cars. It has since been superseded by electrical methods of regulation, and practically all of those now in use are electrically operated.

Q. How many electrical methods of regulating the amount of current generated are in general use?

A. So far as their principle goes, practically all are the same.

They depend upon weakening the excitation of the fields of the generator to cut down the output. It is in the methods of accomplishing this that they differ. In the latter respect they may be divided into two general classes: those that are inherent in the design of the machine, i.e., the regulating device is actually a part of the machine itself; and those in which an external regulator is employed. Those most commonly employed are, in the first class, the bucking-coil winding and the third-brush method; in the second, an external regulator is usually combined with the battery cut-out and designed to keep either the voltage or the current at a uniform value, usually the voltage.

Q. What is a bucking-coil winding, and why is it so called?

A. We have seen that in a series-wound machine all of the current generated in the armature passes through the field windings and energizes the field magnets; in the shunt-wound machine the wires carry only a part of the current which is proportional to the resistance that the shunt winding of the fields bears to the resistance of the outside circuit. As this outside resistance (the load) increases, more current will be diverted through the path of lesser resistance, or the shunt-wound field, and the output of the machine will increase accordingly. In the compound-wound machine, the relation of the series to the shunt winding is such that it is called upon chiefly to help carry any extra load. In other words, as the demands upon the machine increase, the series winding adds its energizing effect to that of the shunt coil. A generator with a bucking-coil winding is a compound-wound machine, but the series winding is in *the opposite direction* from that of the shunt winding. Consequently, instead of adding to the field excitation caused by the latter, it *opposes or bucks* it, and the more current there is produced in the shunt field by the rise in speed, the more the series winding, or bucking coil, tends to neutralize this excess, thus keeping the amount of magnetic effect produced in the field poles practically uniform, regardless of the speed.

Q. What is the third-brush method of regulation?

A. In a conventional shunt-wound generator, the field windings are directly in shunt with the armature through the brushes; hence, a certain proportion of all the current induced in the armature windings will find its way through the field magnet windings, in proportion to their relative resistance to the outside circuit at the time. Where a

third brush is employed, the main brushes are not in shunt with the fields, and they are not depended upon to supply the exciting current for the latter. The third brush instead is used for this purpose. As is well known, the output of a generator depends very largely upon the position of its brushes. In the immediate vicinity of the proper location for a brush, there is a short zone of maximum intensity. As we get away from this toward the next brush, it decreases until at a point midway between the two there is a neutral zone. The third brush is accordingly placed between the two main brushes, and its distance from the nearest main brush determines the amount of current that it diverts from the armature to the field windings. See illustration of Delco generator in section on Methods of Regulation. This method has the advantage of supplying a strong shunt field at low speeds. As the speed increases, the voltage applied to the shunt field decreases, even though that between the two main brushes may have increased.

Regulators

Q. What is a regulator, and what is its purpose?

A. It is an instrument somewhat similar to a battery cut-out, and its purpose is to regulate the output of the generator in order that the latter may not exceed safe limits at high speeds. The regulator is usually combined with the cut-out.

Q. How does the constant-voltage type of regulator operate?

A. The instrument consists of a magnet winding and a pivoted armature, normally held open by a spring and a resistance unit. The winding of the magnet has sufficient resistance to prevent the core becoming energized to a degree where it will attract the armature, unless the voltage exceeds the safe limit determined for the circuit. The voltage increases with the speed of the generator, so that when the latter is driven too fast the attraction of the magnet core for the armature becomes sufficient to overcome the pull of the spring which normally holds the contacts apart. (See description of Bijur voltage regulator.) When the contacts come together, the field circuit of the generator is shunted through the resistance unit; this cuts down the amount of current energizing the fields, the voltage falls off, and the contacts again separate. Unless the speed of the generator is decreased, this action is rapidly repeated, so that the regulator arma-

ture vibrates at a high speed as long as the voltage is sufficiently high to energize the magnet.

Q. What is the principle on which this type of regulator operates?

A. The principle that in a circuit having considerable self-induction the amount of current which may be sent through the circuit will decrease if the current be pulsating instead of steady. Every time the contacts of the regulator open, a pulsation, or surge, of current is sent through the field windings of the generator; when they close because of the higher voltage, the current is shunted through the resistance unit, thus cutting it down. The decrease in the amount of current is in proportion to the number of pulsations per minute, i.e., the rapidity with which the vibrating contact operates. The circuit having considerable self-induction is that of the field winding of the generator, owing to its heavy iron core. (See Induction.)

Q. What is the constant-current type of regulator, and how does it differ from the constant-voltage, or potential, type?

A. It consists of an electromagnet and a spring-controlled pivoted armature, so that it is of practically the same construction as the constant-potential type, but it is connected in circuit with the armature of the generator and it is wound to operate under the influence of the current rather than the voltage. Consequently, the pivoted armature is attracted, opening the circuit when the current exceeds a certain predetermined value, usually 10 amperes. In operation, the armature vibrates the same as in the voltage regulator, but the condition of the charge of the battery has no effect on it, so that when set to limit the current to 10 amperes, it will always charge the battery at approximately that rate regardless of the condition of the battery. The only practical difference is that it is wound to actuate under the influence of changes in the current flow and is connected in the armature circuit, whereas the constant-potential regulator is influenced by variations in the voltage and is connected in the field circuit of the generator. The latter has the advantage of charging the battery at a higher rate when the charge is most needed.

Q. What other forms of regulators are employed on lighting generators?

A. The foregoing comprise practically all of the principles

employed, but the regulators differ more or less in design and operation. For example, in the Bosch-Rushmore generator, a bucking coil is employed in connection with what is termed a ballast resistor, or resistance unit. This is of iron wire, and it is based on the fact that resistance increases very rapidly with the temperature. The size of the wire is such that it allows 10 amperes to flow without undue heating, so that its resistance is practically unchanged; above this point it heats rapidly and increases in resistance so greatly that all excess current is shunted through the bucking coil. In the Splitdorf generator, the regulator is built in, projections of the pole pieces of the field being utilized in connection with special windings, instead of an independent electromagnet as in the Ward-Leonard and the Bijur. In the U.S.L. generator of the inherently regulated type, regulation is accomplished by the combination of a Gramme ring armature, a special arrangement of connections and of the field windings, and the use of only a part of the fields and armature for generating current. The regulation obtained is based on armature reaction and is similar in effect to the third-brush method. The U.S.L. external type of regulator cuts into the generator field circuit a variable resistance consisting of an adjustable carbon pile. In the Adlake regulator, which is of the constant-potential type, a solenoid operates a switch over the contacts of a variable resistance. The plunger of the solenoid is counterbalanced by a weight, which must be raised to operate the switch. It is adjustable by increasing the weight of this counterbalance.

Q. What attention does the regulation of the generator require?

A. This will depend upon the method employed in each case. Where an external regulator is employed, whether of the constant-potential or the constant-current type, the attention required is practically the same as in the case of the battery cut-out. See that the points are not sticking, and when badly burned or pitted, smooth and true up, taking off as little of the contact point as possible to effect this. When the points have become so badly pitted that this cannot be done, new parts will be necessary.

With the third-brush method, the attention required by this brush is the same as that which must be given the other brushes, i.e., sanding-in at intervals and replacement when worn too short to permit the spring to hold the brush firmly against the commutator.

Where the generator fails to produce sufficient current to keep the battery charged, all other parts of the system being in good condition and the car driven long enough in daylight to charge the battery under normal conditions, the position of the third brush may be shifted to increase the output. Care must be taken not to let it come in contact with the main brush. (See Delco instructions.) In the case of a bucking-coil winding, no attention is necessary, as this is an integral part of the machine itself. As the Splitdorf regulator has moving contact points, the attention necessary is the same as that required for an external regulator of this type. Special regulators, such as the U.S.L. external type, require attention covered by the maker's instructions. (See U.S.L. system.)

Q. When the generator fails to keep the battery charged properly, a normal amount of daylight driving being given the car, is the fault most likely to be found in the regulator?

A. No. It is much more likely to be caused by a dirty commutator, worn brushes, loose connections, or some similar cause which inserts extra resistance in the charging circuit. The movement of the regulator armature is very slight, and the current handled by the contact points is small, so that it will seldom be the cause of the trouble. Other causes, such as those above enumerated, should always be sought first. (See instructions under Generator.)

Windings

Q. Are faults in the generator windings frequent?

A. They constitute one of the least frequent sources of trouble with the machine.

Q. What is likely to cause them?

A. Dousing the machine with water is likely to be one of the most frequent causes of short-circuits or grounds in the generator windings. All electrical machinery is intended to be kept dry. Except where provided with a field fuse, running the generator when disconnected from the battery or with the battery removed from the car is another cause. Excessive speed, in some instances, may generate sufficient centrifugal force to lift the armature coils out of their slots so that the insulation becomes abraded by rubbing against the pole pieces, but this is very unusual. In rare instances, a hard kink left in the wire when winding may crystallize the metal

and make it break at that point, due to the vibration. Unless cleaned out at intervals, fine carbon dust from the wear of the brushes may accumulate in the interstices of the windings, and, when aggravated by moisture, this is apt to cause short-circuits.

Q. What are the usual indications of such faults?

A. With a short-circuited generator coil (armature), all other parts of the apparatus and circuits being in good condition, the charging rate will be lower than normal. The ammeter needle will vibrate violently when the engine is running at low speeds, and two or more adjacent commutator bars will burn and blacken. With an open armature coil (broken wire), the indications will be practically the same, and there will be severe sparking at the brushes, causing serious burning of the commutator bar corresponding to the open coil. A grounded armature coil will give the same general indications, and if the machine is a single-unit type, the cranking ability of the starting motor will be seriously impaired. The ammeter, however, will not vibrate as in the former cases. There will be practically no charge from the generator, and the battery will be discharged very rapidly by the starting motor.

In a single-unit machine, when the windings of the generator and the starting motor become interconnected, the indications will be practically the same as those of a grounded armature coil. If the motor windings of a single-unit machine become grounded, there will be an excessive discharge from the battery, while the motor will develop but little power.

Q. How may such faults be located?

A. With the aid of the testing-lamp outfit. Remove the brushes (when replacing them later, be sure to put each brush back in the holder from which it was taken), or the brushes may be insulated from the commutator by placing paper under them. For a grounded coil, place one test point on the commutator and the other on the frame; if grounded, the lamp will light. For interconnected motor and generator windings in a single-unit machine having two commutators, insulate the brushes as mentioned and place the test points one on each commutator. The light will burn if the two windings are connected. For a grounded-motor winding, test from the motor commutator to the frame; the light should not burn if the insulation is all right. For a break or open circuit

in the field winding, touch the terminals of the latter with the test points, the commutator being insulated or the armature removed. The lamp should light. For a blown field fuse on machines so equipped, place the points on the clips; if the fuse is intact, the lamp will light.

Q. Are these tests conclusive?

A. No. They will indicate any of the faults mentioned, but they will not reveal an internal short-circuit in the windings, which cuts some of the armature or field turns out of action but does not break the circuit as a whole. Such a short-circuit reduces the output of the generator and can be determined definitely only by measuring the resistance of the windings. This requires special and expensive testing instruments, such as the Wheatstone bridge, so that where all other tests fail to reveal the cause of a falling off in the output of the generator, it should be sent to the maker for inspection.

Commutator and Brushes

Q. What does a blackened and dirty commutator indicate?

A. Sparking at the brushes or an accumulation of carbon dust due to putting lubricant on the commutator.

Q. What is the cause of sparking at the brushes?

A. Poor brush contact, due to worn brushes; brush-holder springs too loose, so that brushes are not held firmly against the commutator; excessive vibration, which may be due to a bent shaft, an unbalanced gear pinion, or improper mounting; using too much oil, or using grease in the ball bearings, which gets on the commutator and, acting as a solvent for the binder of the carbon, forms a pasty mass which prevents proper brush contact; worn or roughened commutator on which the mica needs undercutting; overload due to failure of regulator or to grounded coils in armature.

Q. What is the remedy for sparking?

A. Clean the commutator with fine sandpaper and sand-in the brushes to a true bearing on the commutator as directed in the Delco instructions. See that the brush springs have sufficient tension to keep the brushes firmly pressed against the commutator when the machine is running. If the mica protrudes above the commutator bars, it must be undercut as directed, and the commutator smoothed down again after the operation to remove any burrs.

Q. Why do some commutators need undercutting and others not?

A. Undercutting is required only on machines equipped with brushes that are softer than the mica. Copper-carbon brushes, as employed on starting motors to reduce the brush resistance, are hard enough to keep the mica worn down with the copper of the commutator itself.

Q. If, after smoothing off and undercutting the mica, the commutator still has an uneven and irregular surface, what is the remedy?

A. The armature should be removed from the machine, and the commutator trued up in the lathe, taking as light a cut as possible consistent with obtaining a true round and smooth surface.

Q. How can excessive commutator wear be prevented?

A. Inspect at regular intervals and on the first sign of sparking smooth up the surface and sand-in the brushes. Keep the commutator clean and do not permit carbon dust or oil to accumulate in the commutator and brush housing. Never replace brushes or brush springs with any but those supplied by the manufacturer for that particular model. The machine will work with any old brush and any old spring that fits, but they will prove detrimental to its operation in a comparatively short time, and its *working* under such conditions will never be satisfactory.

Q. Is discoloration of the commutator ever caused by anything else than sparking?

A. Not actual discoloration which requires cleaning, but the normal operation of the machine produces a purplish blue tinge on the bars, which is sometimes mistaken for discoloration by the inexperienced. This color, in connection with a high polish of the metal, indicates that the commutator is in the best of condition. Once the commutator takes on this high polish, it will operate for long periods without other attention than the removal of dirt by wiping with a clean rag. Sanding to remove this purple tinge is a mistake, as it only destroys the polish without having any beneficial effect.

Q. Is it necessary to lubricate the surface of the commutator?

A. No. The brushes employed are usually of what are termed a self-lubricating type and require no attention in this respect.

Q. Will any harm result from putting light grease, vaseline, or lubricating oil on the surface of the commutator?

A. As all lubricants are insulators to a greater or less extent, the efficiency of the machine will be reduced and, as the voltage is very low, but a slight falling off is necessary to represent a very substantial percentage of the maximum. The use of lubricant of any nature on the commutator also has another harmful effect in that it collects the carbon dust resulting from the wear of the brushes, causing it to lodge against them as well as between the commutator bars.

Q. Why should particular care be taken to remove all carbon dust from the commutator housing of both the generator and the motor (two-unit system) or the single unit where both functions are combined in one machine?

A. Carbon dust is an excellent conductor of electric current and, when spread over the surface of an insulator, it causes the latter to become conducting as well. Consequently, it is likely to short-circuit the commutator bars by lodging between them. It will cause leakage across fiber or other insulating bushing of brush holders when a sufficient deposit accumulates on them. It will penetrate the armature and field windings of the machine and may cause trouble by grounding or short-circuiting them. Especial care should be taken to remove all traces of carbon dust after sanding-in the brushes.

Q. How often should the commutator be inspected?

A. The commutator is the most vulnerable part of any direct-current machine, whether it be a generator or motor, and it should accordingly be inspected at more frequent intervals than any other single part of the entire system. The efficiency of both the generator and the motor depend upon it to a very great extent. Most of the failures of starting and lighting systems that are not due to poor condition of the battery may be traced directly to the commutator.

Q. What is the function of the brushes?

A. To conduct the voltage and current induced in the armature by its revolution through the lines of force created by the magnetic field, to the outer circuit, in the case of an electric generator; and to conduct the operating current to the armature windings from the battery, in the case of the starting motor.

Q. Why must the brushes bear evenly over their entire surface on the commutator?

A. Because their current-carrying capacity depends upon their size, and the latter is based upon the entire surface of the end of the brush making efficient contact. If the brush does not make uniform contact, those parts of it that do not touch the commutator will cause arcing or heavy sparking at the gap thus created, resulting in damage to both the commutator and the brush.

Q. Why are springs of different strengths used on generators and motors of different makes to hold the brushes against the commutator, though the machines are of practically the same capacity, operate at the same voltage, and are in other respects very much alike?

A. The carbon compounds of which the brushes are manufactured differ greatly in their conductivity and resistance offered to the passage of the current, and these differences call for greater or less spring pressure to hold the brush against the commutator surface in order to make efficient contact over the entire surface of the brush. Every maker has his own standard in this particular respect.

Q. Why is it not advisable to use brushes other than those supplied by the manufacturer as replacements on a machine?

A. For the reasons just given above. The manufacturer has adopted certain standards for the operation of his machines, and the brushes supplied have been made particularly to comply with those standards. No other brushes will do so well, and some will result in injury to the machine.

Q. When inspection shows that the brushes have worn down unevenly, what should be done?

A. They should be sanded-in with a strip of fine sandpaper, such as No. 00, preferably already worn if the brushes are very soft. (See instructions for doing this properly in connection with machines of different makes.) No more should be removed than is absolutely necessary to bring the end of the brush to a firm contact all over its bearing surface on the commutator; and the end of the brush, after the completion of the operation, should not show any deep scratches or pit marks. Unless the surface is smooth and true, injurious sparking will result, and the efficiency of the machine will be decreased.

Q. If, with a smooth and true surface, the brush still fails to make good contact, what is the trouble?

A. The brush has probably worn down until it is too short for the spring to exert sufficient force against it to hold it against the

commutator properly, or the spring itself may be at fault. Wear of the brush beyond the point where it is any longer of service will most often be the cause.

Q. Where the brushes are true and are making good contact against the commutator, but the machine is inoperative, all other parts of the system being in good condition, what is likely to be the trouble?

A. One of the pigtails, or short flexible connections, of the brushes may have shaken out from under its spring clip. This breaks the circuit, just as a parted wire or a ruptured connection at a terminal in any other part of the system would.

Q. How often is it necessary to replace the brushes?

A. This differs so much with different makes of machines that it cannot be answered definitely, even as an average. On two-unit systems, the generator brushes will naturally require replacements much sooner than those of the starting motor, as the starting motor is only in operation for very short periods, while the generator is working constantly. On single-unit types, this naturally does not apply, as, whether the armature has one or two sets, they are always in use. Ordinarily, brushes should not require replacement under a year, and frequent instances are known of their having lasted for two years or more. It depends upon the care given the commutator and brushes quite as much as upon the mileage covered, as, if allowed to run dirty for any length of time, the brushes will wear away much faster than if kept in good condition. The best rule for the replacement of the brushes on all makes of machines is to renew them as soon as they have worn to a point where the springs no longer hold them firm against the commutator. When they have reached this condition, the vibration and jolting of the car is likely to shake them out of contact, which results in sparking.

Q. What is the "third brush", and what is its function?

A. This is an extra brush used on a generator. Its purpose is to control the amount of current supplied by the armature to the shunt-field winding as the speed increases. In other words, it regulates the output of the machine and prevents it from being burned out when the speed of the engine becomes very high.

Q. Does it differ from the other brushes in construction or in the care required?

A. It is a carbon brush of the same nature as the others used on the same machine, and the care required to keep it in good condition does not differ. However, it is mounted in an independently adjustable holder so that it may be moved backward or forward with relation to the main brushes in order to increase or decrease the output of the generator. (See instructions [Delco] on this point.)

Q. Is it ever necessary to alter the location of the brushes of a machine?

A. Except on generators fitted with the third-brush method of regulation, on which it may be necessary to shift the main brushes slightly to avoid having the third brush come in contact with one of them when moved to change the output, it should never be necessary to shift the location of the brushes. Brush location has an important bearing on the operation of the machine, and, in designing it, the maker has fixed the location of the brushes to conform to its other characteristics. Many machines have no provision for adjusting the brushes in this respect, while some manufacturers caution the user particularly against altering their location.

Q. How much spring pressure is usually employed to hold the brushes of the generator and starting motor against the commutator?

A. This varies with different makes of machines and should be ascertained from the maker's instructions in every case in order to check up properly. In the various models of the Gray & Davis starting motors, this spring pressure ranges from $2\frac{1}{4}$ to $3\frac{1}{2}$ pounds, which is the minimum necessary. In other words, the brush must be held against the commutator with this amount of pressure in order to operate efficiently. While there will be a loss if the pressure drops below the minimum, there is no advantage in greatly exceeding it, as excess pressure simply causes greater friction loss without any compensating gain in power. Generator-brush pressures are much less than those employed on starting motors, owing to the smaller amount of current handled.

Q. How can the proper spring pressure of the brushes be checked?

A. With the aid of an ordinary spring scale of the direct-pull type, in which the pull on the hook draws the pointer down over the scale. A scale reading to five pounds is adequate for the purpose; one intended for heavy weights is not likely to be so accurate. Attach

the hook of the scale to the brush and pull until the brush is just clear of the commutator. The scale will then register the pull in pounds. Where there is nothing on the brush to which to attach the hook, such as a screw, place a thin piece of wood on the brush face before passing the hook of the scale around it, to prevent injuring the contact face of the brush. In this case, the spring pressure as shown on the scale will exceed the necessary minimum, as the spring must be compressed further than it would be when in operation, in order to operate the scale. This should be allowed for when taking the reading.

Q. When is it advisable to check the spring pressure of the brushes?

A. When there is undue sparking at the commutator, while the commutator and brushes are all in proper condition, i. e., clean, and bearing uniformly over their entire surface so that the sparking is not due to any fault in either of these essentials.

Q. When the brushes and commutator are in good condition and the spring-scale test shows that the brushes are being held against the commutator with the necessary amount of pressure, what is likely to be the cause of the sparking?

A. There may be a short-circuited or open coil in the armature.

STARTING MOTOR

Q. In what way does the starting motor of a two-unit system differ from the generator?

A. It is a simple series-wound machine having but one winding of coarse wire on the fields, and all the current from the battery passes through its armature coils and field windings.

Q. Is it subject to electrical faults other than those already referred to in connection with the generator?

A. No. The care and the nature of the tests required to locate faults are the same. The commutator should be kept clean, brushes bearing firmly on commutator, and all connections kept tight. The same instructions for sanding-in brushes and keeping the commutator in good condition apply as in the case of the generator.

Q. When the starting motor fails to operate, what is likely to be the cause?

A. In the majority of instances, a low state of charge or a

wholly discharged battery will be responsible. If the battery is all right, a loose connection at the battery, switch, or motor, or a short-circuit in some part of this wiring may be the cause. Should the battery be properly charged, all wiring and connections in good condition, switch contacts clean, etc., the starting gears may be binding, owing to dirt or lack of alignment between the motor shaft and the flywheel of the engine. In this case, the motor will attempt to start when the current is first turned on, but will be held fast. Loosen the holding bolts and line up the motor, cleaning the gear teeth if necessary.

Q What is likely to be the cause of the starting motor running slowly and with very little power?

A. Exhausted battery, poor switch contacts, loose connections, partial ground or short-circuit in wiring causing leakage, improperly meshing gears, dirty commutator, brushes making poor contact owing to weak springs or worn brushes, or a ground in the motor itself. The remedies for all these faults have been given already.

Q. When the battery and all connections and wiring are in good condition, but the motor fails to crank the engine, what is likely to be the cause?

A. The engine may be too stiff. If it has been overhauled just previously, the main bearings may have been set up too tight. Test with the starting crank to see if it can be turned over easily by hand. If unusual effort is required, easing off the bearings should remedy the trouble. Should the engine not turn over as soon as the switch is closed, release immediately, as otherwise the battery will be damaged.

Q. When the engine does not start within a few seconds, why is it better to use the starting motor intermittently than to run it continuously until the engine does fire?

A. The intermittent use of the starting motor, say ten seconds at a time, with a pause of half a minute or a minute between attempts is easier on the battery. If allowed to rest for a short period, the storage battery recuperates very rapidly. Consequently, the operation of the starting motor for two minutes, divided into twelve periods of ten seconds each, will not run the battery down to anything like the extent that its continuous operation for the same length of time would. Moreover, this intermittent method of operation increases the chances

of starting under adverse conditions, as, in very cold weather, every time the battery is allowed to rest, it will be able to spin the engine at its normal starting speed, whereas if the starting motor is operated continuously, the battery will become so weak that the engine will be turned over very slowly toward the end of the period in question.

Q. Why is it that a starting motor capable of turning an engine over at a speed anywhere from 75 to 150 r.p.m. will sometimes fail to start the engine, whereas hand cranking subsequently resorted to will succeed?

A. It must be borne in mind that the operation of starting an engine in cold weather involves several factors. (1) The pistons, crankpins and crankshaft (bearings) must be broken away, i.e., forcibly released from the hold that the gummed lubricating oil has on them, before they can be moved. The great difference between the power required to do this in summer and in winter is shown by the greatly increased amount of current used by the starting motor. (2) Gasoline and air must be drawn into the cylinders, to effect which in sufficient quantity to start the engine requires quite a number of revolutions. (3) The gasoline must be vaporized so that it will mix with the air, which involves more turning of the engine to create the necessary heat by compression in the combustion chambers and the friction of the moving parts. In the application of energy in any form, two factors are always involved, i.e., the unit, or quantity of power applied, and the length of time during which it is applied. The starting motor cranks the engine at a comparatively high speed for a brief period. In hand cranking, a smaller unit of power is employed, and the speed of cranking is accordingly less, but its application is continued for a much longer time. The failure of the starting motor is not due to its inferiority to hand cranking, but simply to the fact that the battery has become exhausted. Success in hand cranking where the starting motor has failed is usually due to the fact that the starting motor has done all the preliminary work, failing in the end simply because the storage battery did not have sufficient energy to finish the task. No electrical starting system can ever be any stronger than its storage battery, or source of energy.

Q. Why is it not necessary to protect the starting motor or its circuit by fuses or other protective devices as in the case of the generator?

A. A simple series-wound machine (practically all electric starting motors are of this type) is capable of standing exceedingly heavy overloads for short periods, it being nothing unusual for these small motors to have a factor of safety of five, or even seven, for a limited time, that is, they will take five to seven times the normal amount of current for a brief period without injury. As a matter of fact, the starting motor can utilize all the current the battery is capable of supplying, provided the motor is free to move. If the engine is stuck fast or some part of the starting system has gone wrong so that the electric motor cannot turn over, then there is danger that the motor may be damaged unless the switch is opened at once. This, together with the fact that the maximum load which may be placed on the motor at different times is such a variable quantity, would make it a difficult matter to provide a fuse that would not blow unnecessarily. The only object of the fuse would be to protect the motor windings, and, as the latter can stand all the current the battery can supply, the only source of danger is the possibility of the motor being held fast so that its armature cannot revolve.

WIRING SYSTEMS

Different Plans

Q. What is the difference between the single-wire and the two-wire systems?

A. In the single-wire there is but one connection to the operating circuit by means of a wire or cable, the circuit being completed in every instance by *grounding* the other side of the circuit. For this reason the single-wire is also referred to as a grounded system. In the two-wire system, copper wires or cables are employed to complete the circuits between the generator and battery and between the battery and the starting motor, as well as to the lamps.

Q. What forms the return circuit of a single-wire system?

A. The steel frame of the chassis.

Q. How are the various circuits grounded?

A. In the case of the battery, a special ground connection is usually made by drilling the frame and fastening a clamp to it. The ground cable from the battery is attached to this clamp. The generator and starting motor are grounded internally, i.e., the end of a winding or of a brush lead that would be taken out to form the

return side of a two-wire system is connected to the frame of the machine, and the latter completes the connection to the chassis through its holding bolts or other means of attachment. One side of all lamp sockets is usually grounded, so that the bulb itself completes the connection when fastened in place. Sometimes there is a special ground connection from the battery for the return side of the ignition or lighting circuits, and this ground wire is fused.

Q. What are the advantages and disadvantages of the single-wire system?

A. It greatly simplifies the wiring, as but one wire connection is necessary to the apparatus for each circuit, but this advantage renders it more susceptible to derangement through unintentional grounds or short-circuits, since the touching of any metal part of the chassis by a bare wire will cause a short-circuit. This depends to a very great extent, however, on the thoroughness with which the wiring is protected, and, with the armored cables or loom and the junction boxes used on modern installations, it is reduced to a point where both systems are practically on a par in this respect.

Q. What are the advantages and disadvantages of the two-wire system?

A. Each circuit is complete in itself thus rendering it easier to locate faults, while no one connection coming in contact with a metal part of the chassis will cause a ground. The wiring itself, however, is much more complicated, and, with the small space available on the bulb connections, it is more difficult to insulate them properly.

Q. Which system of wiring is favored?

A. The single-wire system will be found on the majority of cars, and the number of makers adopting it is steadily increasing.

Faults in Circuit

Q. What is the difference between a ground and a short-circuit?

A. So far as the effect produced is concerned, they are the same; the difference in the terms referring solely to the method of producing it. For example, if the cable of the starting motor circuit becomes abraded and the bare part touches the chassis or some

connecting part of metal, this is a *ground*. But it is also a short-circuit in that the circuit to the battery is completed through a shorter path than that intended. On the other hand, if, in a two-wire system, the two cables of the same circuit become chafed close together and their bared parts touch, this is a short-circuit, but it is not a ground. For all practical purposes, however, the two terms are really interchangeable when applied to faults in the circuit. (See Gray & Davis instructions.)

Q. How may grounds be located in a single-wire system?

A. In any of the fused circuits, the fuse will immediately blow out. Remove the fuse cartridge and shake it; if it rattles, the fuse wire has melted and the fuse is blown. If it does not rattle, short-circuit the fuse clips with the pliers or a piece of metal; a spark will indicate the completion of the circuit and will also indicate that the fuse has blown. If, on bridging the fuse clips, the lamp lights, or other apparatus on the circuit operates, the short-circuit was only temporary. This does not mean, however, that the fault has been remedied; the vibration of the car may have shaken whatever caused it out of contact and further vibration sooner or later will renew the contact with the same result. Inspect the wiring of that particular circuit and note whether the insulation is intact throughout its length. See that no frayed ends are making contact at any of the connections and that the latter are all tight and clean. In case the lamp does not light on bridging the fuse clips, see if the bulb has blown out; if not, use the test lamp by applying one point to the terminal and the other to various points along the wiring.

Q. Does the blowing of a fuse always indicate a fault in the wiring?

A. No. A bulb, in blowing out, frequently will cause a temporary short-circuit that will blow the fuse. To determine this, apply the points of the test-lamp outfit to the bulb contacts; if the test lamp lights, the bulb is short-circuited, and a new fuse and bulb may be inserted without further inspection of the circuit. In case the test lamp does not light on this test, it does not necessarily indicate a fault in the wiring of that circuit, though inspection is recommended before putting in new fuse and bulb. The blowing out of the bulb may cause a short-circuit, which is ruptured by the

current burning away the light metal parts that were in contact, such as a small piece of the filament.

Q. Can a short-circuit or ground occur without blowing a fuse?

A. Yes. No fuses are employed on starting-motor circuits owing to the very heavy current used and its great variation depending upon the conditions, such as extreme cold gumming the lubricating oil, tight bearings, binding of the pinion and gear, sprung shaft, starting motor out of alignment, or the like. On other circuits, the amount of current leaking through the fault in the circuit may not be sufficient to blow the fuse, as the capacity of the latter is such that it will carry the maximum current which the apparatus in that circuit will carry without damage—usually 5 or 10 amperes on lighting circuits and 10 amperes on generator-field circuits.

Q. How can such faults be noted?

A. The ammeter, or indicator, will show a discharge reading when the engine is idle and all lamps are switched off.

Q. What is the usual nature of such a fault?

A. The battery cut-out may have failed to open the circuit completely; a frayed end of the stranded wire at one of its connections may be making light contact which will permit a small amount of current to pass; a particle of foreign matter of high resistance may be bridging a gap either at the cut-out or some other part of the circuit; or the ignition switch may have been left on the *battery* contact so that current is flowing through the ignition coil.

Q. How may faults be located in a two-wire system?

A. With the aid of the test lamp, placing the points along the two wires of the circuit at fault from one set of terminal connections to the other, examine all connections in the circuit in question; note whether any wires have frayed ends and, if so, wind them tight together and dip in molten solder. See whether any moving part is in contact with one or both of the wires and whether the insulation of the latter has been worn off. In some two-wire systems there is a ground connection to the battery for the ignition system, in which case tests for grounds in the circuit in question must also be made. Examine the ignition switch for faults; also the switch of the circuit under test. This applies to single-wire as well as to two-wire systems.

Q. What is one of the most frequent causes of short-circuits in a two-wire system?

A. The bulbs and their sockets, owing to the very small amount of space available for the insulation. Dirt or particles of metal may be bridging the small gaps between their insulated contacts. A blown-out bulb also may be responsible, as previously mentioned.

Proper Conduction

Q. Why are different sizes of wire employed in the various circuits?

A. To permit the passage of the maximum current necessary in each circuit consistent with the minimum drop in voltage due to the resistance of the wire and its connections. The voltages employed are so low that any substantial drop due to this cause would seriously impair the efficiency of the system and particularly of the starting motor. For the latter the cables employed are not only large, but they are also made as short and direct as possible to save current as well as expense in the installation.

Q. What is the smallest wire that should be employed in automobile wiring?

A. No. 14 B. & S. gage, and this should be used only for the tail lamp, dash lamp, primary circuit of the ignition, or similar purpose. No. 10 or No. 12 is usually employed for the other lighting circuits.

Q. When, in making alterations on a car, it becomes necessary to extend a circuit, what should be done?

A. The ends of the wires should be scraped clean and bright for at least 2 inches, and a lineman's joint made with the aid of the pliers to insure having it tight. A lineman's joint is made by crossing the bared ends of the wires at their centers at right angles to each other, then wrapping or coiling each extending end tight around the opposite wire; the joint then should be soldered and well taped. A circuit should be extended only by using wire of the same size and character of insulation. None of the foregoing applies to the starting-motor circuit. It is inadvisable to lengthen this circuit if avoidable, but in the rare instances when it would be necessary, new cable of the same size or larger and with the same insulation should be cut to the proper length and the old cable

discarded. All terminals should be solidly fastened to the new cable by soldering.

Q. Why is it necessary to use such heavy cable for the connection of the starting motor to the battery?

A. It is essential that the exceedingly heavy starting current be transmitted with the minimum of loss.

Q. What is considered the minimum permissible loss in the starting-system wiring?

A. One maker specifies that the starting cable must be large enough to transmit a maximum current of 400 amperes with not over one-fourth volt total loss.

Q. Why is it important to hold the voltage drop down to a maximum so small as to be negligible in almost any other application?

A. Owing to the heavy current necessary, as a drop of but $\frac{1}{4}$ volt in potential with a current of 400 amperes represents a loss of 100 watts, or close to $\frac{1}{7}$ horsepower. Of course, the current seldom reaches such a high value as this except when a motor is exceptionally stiff, as in severe cold weather or just after its bearings have been set up very tight; moreover, this loss takes place at the instant of starting only, but it is just at this time that the highest efficiency and full battery power is needed to start without spinning the engine too much.

Q. On some of the early systems whose efficiency was not of the best, how can the proper size of cable to use between the starting motor and battery be determined?

A. Test the starting motor with a high-reading ammeter (scale should read to at least 300 amperes) after having made certain by hydrometer and voltage tests that the storage battery is fully charged. (See instructions regarding this.) Carefully note ammeter reading exactly at instant of closing switch, to determine maximum current flow. Measure the length of cable between the battery and the starting motor, i.e., both sides of starting switch. Then maximum starting current times 10.7 times number of feet of cable used, divided by .25 will give the cross-section of the wire in circular mills. For example, assume that the starting motor required a maximum of 300 amperes momentarily to break away the engine, and five feet of cable are employed for the connections. Then

$$\frac{300\times 10.7\times 5}{25}=128{,}400 \text{ circular mills}$$

By referring to Table I, Part I, which gives the various size wires in circular mills and their equivalent in gage sizes, it will be noted that the closest approach to this is No. 00 cable, which is 133,079 circular mills, so that the largest size cable would have to be used. If the starting cable used on an old system which does not show particularly good efficiency is much smaller than this, it would probably be an advantage to replace it with larger cable, assuming, of course, that every other part of the system is in good condition and working properly.

Q. Why should connections be inspected frequently?

A. The vibration and jolting to which they are subjected in service is so severe that no mechanical joint can be depended upon to remain tight indefinitely.

Q. What harm does a loose or dirty connection occasion?

A. A loose connection causes the formation of an arc between its contacts whenever vibration causes the parts to separate temporarily. This wastes current and burns the metal away, leaving oxidized surfaces which are partially insulating, thus increasing the resistance at the connection. Dirt getting between the surfaces of the connector has the same effect; the resistance is increased and there is a correspondingly increased drop in the voltage of the circuit, which cuts down its efficiency.

Q. Why should all terminals be well taped when the battery, starting motor, generator, or other apparatus is temporarily disconnected for purposes of inspection or test?

A. To prevent accidental short-circuits which would be caused by these terminals coming in contact with any metal part of the chassis on a single-wire system. Such a short-circuit would ruin the battery and burn out any lamps that happened to be included in the circuit. This precaution applies with equal force to the two-wire systems, as in this case the terminals of the different wires might come together, or there might be a ground connection in the system.

PROTECTIVE AND OPERATIVE DEVICES

Q. What are the protective devices usually employed on electric systems?

A. Fuses in the separate lamp circuits, in the ground con-

nection, and in the field circuit of the generator on some machines; battery cut-out for the charging circuit; circuit-breaker which takes the place of the fuses.

Fuses

Q. What is a fuse and what is its function?

A. A fuse consists of a piece of wire of an alloy which melts at a low temperature and which will only carry a certain amount of current without melting, the latter depending upon the diameter of the wire, i.e., cross-section and the nature of the alloy. The fuse is usually in the form of a cartridge, the wire being encased in an insulating tube having brass ends, to which the ends of the wire are soldered. These brass ends are pressed into spring clips to put the fuse in circuit. In some cases open fuse blocks are employed, the wire itself simply being clamped under the screw connectors on the porcelain block. The function of the fuse is to protect the battery and the lamps when, by reason of a ground or short-circuit in the wiring, an excessive amount of current flows.

Q. When a fuse blows out what should be done?

A. Investigate the cause before replacing it with a new one. (See Wiring Systems.)

Q. Is it permissible to bridge the fuse gap with a piece of copper wire when no replacements are at hand?

A. Only in cases of emergency and after the short-circuit which has caused the fuse to blow has been remedied. The finest size of copper wire at hand, such as a single strand from a piece of lamp cord, should be used. If this burns out, there being no ground or short-circuit in the wiring, use two strands. Remove the wire as soon as a new fuse is obtainable.

Q. Why are fuses not employed in the starting-motor circuit?

A. In the starting circuit the current necessary is so heavy and varies so widely with the conditions that it would not be practicable to provide a protecting fuse.

Q. What does the intermittent blowing of the fuse on the same circuit indicate?

A. A short-circuit that is caused by the vibration, or jolting, of the car. The wire, lamp socket, or other part of the circuit that is at fault is shaken loose at times so that the circuit is operative, and a new

fuse may be inserted without instantly blowing, as it would do were the short-circuit constant. This is often the case as the car is stopped to inspect the wiring and insert the new fuse, and standing still lets the part drop out of contact; starting up shakes it into contact once more and blows the new fuse. Loose connections, wires with abraded insulation, and bulbs loosely inserted in their sockets are apt to cause trouble of this nature.

Q. Does the blowing out of a fuse necessarily indicate a fault in the wiring or in some other part of the system?

A. No, since a bulb in burning out will frequently cause the fuse to blow out. This is due to the fact that in breaking, the end of the parted filament of the bulb may fall across the other terminal where it comes through the glass, thus causing either a short-circuit or such a reduction in the ordinary resistance as to permit a much heavier rush of current than normal, with the result that the fuse goes. To test, leave burnt-out bulb in place temporarily; short-circuit fuse clips with screw driver or pliers, just touching them momentarily; if no spark results, replace bulb with a new one and test again; if a spark occurs, remove old bulb and test again with no lamp in place; then if no spark occurs in bridging the fuse terminals, the circuit is all right, and the fuse may be replaced.

Q. When all the lighting fuses blow out at once, what does this indicate?

A. A short-circuit across the lighting-switch terminals would cause this. In some switches with exposed rear terminals, it is possible to place a screwdriver or similar piece of metal in such a position that it bridges practically all the switch terminals. If the lighting switches were all closed at the time, this would short-circuit them.

Circuit-Breaker

Q. What is a circuit-breaker, and what is its function?

A. The circuit-breaker is an electromagnet with a pivoted armature and contacts, similar in principle to the battery cut-out. All the current used in the various circuits, except that of the starting motor, passes through it, and its contacts normally remain closed. The winding of the magnet coil is such that the normal current used by the lamps or ignition does not affect it, but the passage of an excessive amount of current will energize the magnet, attract

the armature, and break the circuit. The spring holding the armature away from the magnet will again close the circuit, and the circuit-breaker will vibrate until the cause has been removed. This is usually a ground or short-circuit. The function of the circuit-breaker is to protect the battery and lamps in place of the usual fuses.

Q. If the circuit-breaker operates when there are no faults in the wiring, what is likely to be the cause?

A. Its spring may have become weakened so that the vibration of the car causes it to operate on less current. The Delco circuit-breaker is designed to operate on 25 amperes or more, but, once started, a current of 3 to 5 amperes will keep it vibrating. If tests show that no faults in the wiring or connections exist, increase the spring tension with the ammeter in circuit until the reading of the latter indicates that the circuit-breaker is not operating on the current of less value than that intended. See that the contacts are clean and true.

Battery Cut-Out

Q. What is a battery cut-out?

A. It is an automatic double-acting switch which is closed by the voltage of the generator and opened by the current from the battery.

Q. Of what does it consist?

A. It is essentially a double-wound electromagnet with a pivoted armature and a pair of contacts. One winding, known as the *voltage coil*, is of fine wire and is permanently in circuit with the generator. The second winding of coarse wire is termed the *current coil* and is put in circuit by the contacts.

Q. Why is a cut-out necessary?

A. To protect the storage battery. When the generator speed falls below a certain point, it no longer produces sufficient voltage to charge the battery, and the latter then would discharge through the generator windings if not prevented. This discharge would always take place when the generator was idle, except for the cut-out.

Q. How does it operate?

A. When the generator voltage approaches the value necessary for charging, it energizes the magnet through the voltage

coil and closes the contacts, cutting in the current coil, which further excites the magnet and holds the contacts firmly together. The closing of these contacts puts the battery in circuit and it begins to charge. As soon as the generator speed falls below the point necessary for charging, the battery voltage overcomes that of the generator and sends a current in the reverse direction through the current coil, causing the contacts to separate and cutting the battery out of the charging circuit.

Q. If the generator is run for any length of time at or near this critical speed, what is to prevent the cut-out from vibrating constantly instead of working positively one way or the other?

A. The resistance of the windings is so proportioned that there is a difference of 1 to 2 volts between the cutting-in and the cutting-out points.

Q. What is the result when the battery cut-out—which is variously termed a cut-out, a circuit-breaker, an automatic switch, and a reverse-current relay or an automatic relay—fails to operate?

A. If it fails to cut in, i.e., the contacts do not come together, the battery does not charge and will quickly show a falling-off in capacity, such as inability to operate the starting motor properly or to light the lamps to full brilliance. If it fails to cut out, the battery charge will be wasted through the generator windings with the same indications of lack of capacity.

Q. What is the most frequent cause of trouble?

A. Automatic cut-outs have been perfected to a point where but little trouble occurs. Freezing or sticking together of the contacts due to excessive current will most often be found to be the cause of the device failing to cut out when the generator is stopped. The points should be cleaned and trued up as described in previous instructions. Loose or dirty connections making poor contact may insert sufficient extra resistance in the circuit to prevent the device from cutting in at the proper point. Excessive vibration, particularly when the cut-out is mounted on the dash, may prevent the contacts from staying together as they should when the engine is running at or above the proper speed. See that the cut-out is solidly mounted. Temporary loss of battery capacity may be due to slow driving over rough roads at about the speed at which the cut-out is designed to put the battery in circuit.

Q. None of the above causes existing, what further tests may be made?

A. The windings may be tested as already described for the generator windings, but trouble from this source is equally rare. If the contacts are clean and true and the connections are tight, look for a loose connection elsewhere, as at the generator or battery or the ground on the frame. A loose connection vibrates when the car is moving, constantly opening and closing the circuit and causing the cut-out to do likewise, so that the battery does not charge. A wire from which the insulation has been abraded will also vibrate, owing to the movement, causing an intermittent short-circuit. With all contacts and connections in good condition, failure to cut out indicates a ground or short-circuit between the battery and cut-out; failure to cut in indicates similar trouble between the generator and the cut-out.

Q. Is a battery cut-out necessary on every electrical system?

A. No. On single-unit systems of the type of the Dyneto, in which the generator becomes *motorized* as soon as its speed and consequently its voltage drops below a certain point, the battery is always in circuit. A plain knife-blade switch, which also controls the ignition, is closed to start and left closed as long as the car is running. But the engine must not be allowed to run at a speed below which it generates sufficient voltage to charge the battery, nor must the switch be left closed when the engine is not running; otherwise, the battery will discharge through the generator windings.

Q. After having trued up points of a battery cut-out, what precautions should be taken in adjusting them?

A. To insure proper operation, they must be set to the distances given in the manufacturer's instructions. This refers not only to the gap between the contact points themselves, but also to the distance that the armature must be set from its backstop when the points are open and to the air gap between the armature and the magnet. These distances are very small in every case, and it is important that they be adjusted accurately. They differ slightly on cut-outs of different makes and also on different models of the same make. For example, in the Gray & Davis cut-out, the distance between the contact points should be .015, the air gap between the armature and its backstop not less than .010, and the armature air gap, or distance between the armature and the magnet face, .030. These dimensions

refer to the flexible, or spring-arm type, while in the solid-arm type of the same make, they are .010 for the distance between the contact points and .015 for the armature air gap, it being necessary that the armature should be set parallel with the pole face of the magnet.

Q. How can these small distances be accurately determined with the facilities ordinarily found in a repair shop?

A. The manufacturers usually supply a small adjusting wrench, the different edges of which have been ground to varying thicknesses representing the proper distances for the various gaps. Lacking one of these, small pieces of strip brass or steel may be ground or filed down to the proper size and gauged with a micrometer, which should be part of the equipment of every garage. The strips should be stamped with the dimensions and name of gap for identification.

Q. How often will the point of a battery cut-out need adjustment, or truing up?

A. Service conditions vary so greatly that it is impossible to give any definite average for this, particularly as the instruments themselves also are a variable quantity, but, under ordinarily favorable conditions, they should not require attention more than once a year.

Contact Points

Q. Why is it necessary to make contact points of such an expensive metal as platinum, and why is the latter sometimes alloyed with irridium?

A. There is no other metal which withstands the oxidizing effect of the electric arc and still maintains a clean and bright conducting surface as does platinum. Irridium is added to make the platinum harder, so that it will be more durable. On cheaply made instruments in which no platinum has been used in the contacts, trouble will be experienced constantly with the contacts.

Q. Is there any substitute for platinum or any metal that approaches it in adaptability for contact points?

A. There is no substitute for platinum, and the only metal that approaches it is silver. Where contact points only separate occasionally at intervals, as in the Remy thermoelectric switch, the use of silver contacts is permissible; but in a battery cut-out, or a regulator in which the vibration of the points is more or less constant, nothing will serve so reliably as platinum.

Q. What is the cause of the platinum contacts burning into such irregular ragged forms?

A. When a current of electricity passes through a contact of this nature, the material of the positive electrode (i.e., contact point connected to the positive side of the circuit) is carried over by the current in the shape of metallic vapor, or infinitely fine particles, and deposited on the negative electrode. The positive consequently takes on the form of a sharp point, while the negative has a depression formed in it, usually referred to as a "peak and crater", which the two points resemble in miniature after long use. This peak and crater effect is much more noticeable in an old-style carbon arc lamp after it has been burning only a few hours.

Q. What can be done to prevent this?

A. The passing of the metal from one electrode to the other cannot be prevented, as it is a function of any arc or spark. It can be minimized, however, by keeping the contacts in good condition so that the sparking is reduced to a minimum.

Q. Can the formation of the pack and crater effect, which so greatly reduces the efficiency of the contacts, be avoided?

A. The use of a reversing switch in the circuit, as in the case of the magneto or the battery-type interrupter which changes the direction in which the current flows through the points every time it is turned on, will overcome this. Where there is no reversing switch in the ignition circuit or where one cannot be used, attention to the points at regular intervals will prevent this effect from reaching a stage where most of the point has to be filed away to true it up.

Q. In the use of the file, sandpaper, or emery cloth in this connection, just what is meant by truing the points up?

A. Their surfaces must be made exactly parallel to one another so that when the points come together they touch uniformly over their entire surfaces. In the hands of the unskilled user, there is a tendency to bear down sidewise with the file, thus forming rounded edges on the points. In addition to having the faces of the two points perfectly parallel, the face of each point must be at right angles to its sides. Otherwise, there is bound to be unnecessary sparking between the points, and this causes them to burn away again much sooner. It is scarcely necessary to add that as little as possible of the metal should be removed. As long as there is enough of the platinum left

to make true parallel surfaces, the points need not be replaced if the means for adjustment permits utilizing them when worn far down.

Q. What is the cause of the points freezing, or sticking, together?

A. Permitting them to wear down to a point where they are in very poor condition and where the gap between parts of their surfaces causes the formation of a heavy arc, or hot flash of current, which practically welds them together. By giving them the necessary attention at regular intervals, this may be avoided.

Q. How often should the contact points need attention?

A. When new, they should run for a year or more without any attention. After they have been trued up, the succeeding interval will often depend upon the skill and care with which this has been carried out.

Switches

Q. How do switches as employed on the automobile differ in principle and operation?

A. Starting-circuit switches are either of the knife-blade or the flat-contact type, while in the majority of cases the lighting switches are of the push-button type, though knife-blade switches are used for this purpose also. In some instances, one of the brushes of the machine is made to serve as a switch, as in the Delco. Ordinarily, the switch is normally held open by a spring and is closed by foot pressure, the spring returning it to the open position as soon as released. A variation of this is the Westinghouse electromagnetically operated switch in which a solenoid takes the place of foot operation. The circuit of the solenoid is controlled by a spring push button, which is normally held out of contact. Single-unit systems, such as the Dyneto, in which the machine automatically becomes motorized when the speed drops below a certain point, are controlled by a standard single-throw single-pole knife-blade switch which is left closed as long as the machine is running.

Q. What faults may be looked for in switches?

A. Loose connections; weakening of the spring; burning of the contact faces in the knife-blade type, due to arcing caused by releasing too slowly; dirt or other insulating substance accumulating on the contact faces of the flat-contact type; failure to release through binding.

Q. Why is it important to keep the switch contact faces clean and bright?

A. Dirt or burned surfaces increase the resistance and cause a drop in the voltage at the starting motor. The energy represented by an electric current is a measure of the volume or amperes times the voltage or pressure under which it flows, and, as such low voltages are used, only a slight falling off represents a serious percentage of the total potential. With a dirty switch or one that makes poor contact, current that should be utilized in the starting motor is wasted in overcoming the resistance of the switch.

Q. Why is it inadvisable to insert an extra switch in the starting circuit, as is done in some cases by owners to insure against theft?

A. Because of the drop in voltage. The loss in switches as designed for lighting circuits is about 1 per cent, or a little over 1 volt. If the same switch is used on the low voltage of the starter system, the loss is then equivalent to about 10 per cent.

LIGHTING AND INDICATORS

Lamps

Q. How many types of bulbs are there in general use on automobiles?

A. Four: miniature and candelabra screw base, and single- and double-contact bayonet-lock base, both of the latter being of the candelabra size.

Q. Are these types equally favored?

A. No. The screw-base type, particularly in the miniature size, will be found only on old cars, and this type, generally speaking, is practically obsolete on the automobile, as the vibration tends to unscrew the lamp. Of the bayonet-lock type, the single-contact style is steadily gaining favor. Ten million bulbs for automobile lighting were produced in 1915 (S.A.E. report) and of these 67 per cent were of the single-contact type.

Q. In how many different voltages are these bulbs made?

A. Four: a 6—8-volt bulb for a 3-cell or 6-volt system; 12—16-volt bulb for 6-cell or 12-volt systems; and 18—24-volt bulbs for 9-cell systems; 3—4-volt bulbs for tail-light and dash-light use, where these lights are burned in series on a 6-volt system.

Q. Are these the only voltages in which the bulbs are made?

A. No. They are the types that are being standardized to reduce the stock of replacements that it is necessary for a garage to carry. It has been customary for the lamp manufacturer to supply bulbs made exactly for any voltage that the maker of the electric system ordered. Taking into consideration only the standard sizes now listed for use on 3-, 6-, and 9-cell systems, and the different bases regularly used, there are about twenty-four different bulbs that should be stocked by a garage. In addition, about forty other sizes are in general use, and if individual voltages had to be supplied, considering the different standard bases, a stock of over two-hundred different bulb sizes would be required.

Q. Why is the voltage of a bulb expressed as "6—8", "12—16", etc.?

A. Owing to the rise and fall of the battery voltage according to its state of charge, this variation must be provided for, or the lamps would be burned out when the battery was fully charged. Headlight bulbs for 3-cell systems are made for $6\frac{1}{2}$ volts, while the side, rear, and speedometer lights are made for $6\frac{3}{4}$ volts, owing to the lesser voltage drop in their circuits, but they will all operate satisfactorily on a potential that does not exceed 8 volts or does not drop below 6 volts.

Q. When all the lamps burn dimly, what is the cause?

A. The battery is nearly exhausted, in which case its voltage will be only 5.2 to 5.5 volts for a 3-cell system. The car should be run with as few lights as necessary to permit the generator to charge the battery quickly.

Q. What is the cause of one light failing?

A. Bulb burned out or its fuse blown; examine the fuse before replacing the bulb and if blown, examine the wiring before putting in a new bulb. Poor contact; see that the lamp is put in properly and turned to lock it in place. A double-contact bulb may have been put in single-contact socket, or *vice versa*.

Q. Why will one lamp burn much brighter than the other?

A. A replacement may have been made with a bulb of higher voltage; a 12-volt bulb will give only a dull red glow on a 3-cell system. Where the difference is not so marked as this, but still very perceptible, it may be due to the difference in the age of the

lamps. As a bulb grows old in service, its filament resistance increases, so that it does not take so much current and will not burn as brightly as when new.

Q. Will the failure of a bulb cause its fuse to blow though there is no fault in its circuit?

A. This sometimes happens owing to the breaking down of the filament, causing a short-circuit when the lamp fails.

Q. Can the proper voltage bulbs needed for any system always be told simply by taking the total voltage of the battery, i.e., the number of cells times 2?

A. No. Always examine the burned out bulb and replace with one of the same kind. Many 6-cell systems use 6-volt lamps and are known as 12—6-volt systems. The battery is divided into two groups in series parallel for lighting and sometimes for charging, all the cells being in series for starting. Other arbitrary voltages are also adopted; for example, 14-volt bulbs are used on 12-cell systems, the battery being divided in the same manner, so that this would be a 24—12-volt system. The only safe way to order replacements is to give the voltage on the printed label on the old bulb and state the make of the system on which it is to be used.

Q. What type of bulb is used where the current is taken from the magneto, as on the Ford?

A. As supplied by the maker, only the headlights are wired, and they are in series, and in recent models a 9-volt bulb is used, but the above instructions for replacements will apply here also. Ordinarily, double-contact bulbs are required, unless the fixtures are insulated from one another, in which case the single-contact type can be used.

Q. Why is a bulb of a voltage lower than that of the system itself often employed on 6-, 9-, and 12-cell systems?

A. The lower the voltage, the thicker the filament can be made. A short comparatively thick filament concentrates the light and makes the bulb easier to focus; it is also much more durable than the thin filament required for higher voltages.

Q. Under what conditions will the best results be obtained from the head lamps?

A. When the bulbs are in proper focus with the lamp reflectors. The usual focal length for headlight bulbs is $\frac{13}{16}$ inch, and the

focal length of the reflector is made greater than this to permit of adjustment. The center of the filament should be back of the focus of the reflector to spread the beam of light. In this position a greater number of the light rays are utilized and redirected by the reflector, producing a higher beam candlepower. If the center of the filament is forward of the focus, the lower part of the reflector will produce the most glare and throw it into the eyes of pedestrians and approaching drivers.

Q. How can the headlights be focused?

A. Place the car in position where light can be directed against a wall about 100 feet distant. Adjust the bulbs backward or forward until the spotlight on the wall is most brilliant and free from black rings and streaks. When this position is found, lock the bulb securely in place. Focus each headlight separately. See that the lamp brackets are set so that the light is being projected directly ahead.

Q. How can metal headlight reflectors be cleaned when discolored?

A. Wash by directing a gentle stream of cold water against the surfaces and allow to dry without touching them. The reflectors should never be rubbed with cloth or paper as it will scratch the highly polished surfaces. If they become very dull, it will be necessary to have them replated.

Q. What is the meaning of the identification marks usually placed on bulbs, in addition to the voltage, such as "G-6"?

A. This refers to the size and shape of the bulb. The diameter of the glass bulb is expressed in eighths of an inch and its shape by a prefixed *G* for round (globular), *T* for tubular, *S* for straight-side, etc. Thus, G-6 is a round bulb $\frac{6}{8}$ inch or $\frac{3}{4}$ inch in diameter.

Instruments

Q. What instruments ordinarily are employed in connection with electric systems on the automobile?

A. Either a double-reading ammeter, a volt-ammeter, or an indicator, the first named being employed generally. The ammeter shows whether the battery is charging or discharging or whether no current is passing; the indicator reads either *Off* or *On*; while the voltammeter gives the voltage, usually upon pressing a button to put it into operation, in addition to the readings already mentioned.

Q. On what circuits are the indicating instruments placed?

A. The charging circuit from the generator to the battery, and the lamp and ignition circuits.

Q. Why is an ammeter not used for the starting-motor circuit?

A. The current is so heavy and varies so greatly with the conditions that an ammeter designed to give an accurate reading of it would not be sensitive enough to indicate the smaller amounts of current used by the lamps, or produced by the generator for charging. Furthermore, the starting motor is intended only to be used for very short periods, while the other circuits are in constant use.

Q. Do the small ammeters employed fail very often?

A. Considering the unusually severe treatment to which they are subjected by the vibration and jolting of the car, their failure is comparatively rare, but as the conditions are so severe for a sensitive indicating instrument, too much dependence should not be placed on the ammeter reading when making tests.

Q. What are the usual causes of failure?

A. Failure to indicate—the generator, wiring, and other parts of the circuit being in good operative condition—may be caused by the pointer becoming bent, so as to bind it; the pointer may have been shaken off its base altogether by the jolting, or one of its connections may have sprung loose from the same cause.

Q. How can the ammeter reading be checked?

A. By inserting the portable testing voltammeter in circuit with it, using the 30-ampere shunt and comparing the readings. The dash ammeter must not be expected to give as accurate a reading as the finer portable instrument. Failing the latter, a spare dash ammeter may be employed in the same manner and the spare may be tested beforehand by connecting to a battery of 4 dry cells in series; if brand new, they should give a reading of 18 to 20 amperes. Do not keep the ammeter in circuit any longer than necessary to obtain the reading, as it only runs the cells down needlessly.

Q. Should an ammeter ever be used in testing the storage battery?

A. No. Because it practically would short-circuit the battery, burn out the instrument, and damage the battery itself. Nothing but a voltmeter should be employed for this purpose, as its high

resistance coil permits only a small amount of current to pass. An ammeter reading from a storage battery gives no indication whatever of its condition, whereas the voltage affords a close check on the state of charge, varying from 1.75 for a completely discharged cell to 2.55 volts for a fully charged one, the readings always being taken when the battery is either charging or discharging. The voltage on discharge will not be as high as on charge, the conditions otherwise being the same.

Q. Why are indicators employed on some systems instead of ammeters?

A. As the indicator is not designed to give a quantitative reading, it need not be so sensitive as an ammeter and accordingly can be made more durable.

Q. What are the most frequent causes of failure of an indicator?

A. Usually of a mechanical nature caused by the jolting, such as the target being shaken off its bearings, broken wire, etc.

Q. When the engine is running slowly, and the ammeter or the indicator flutters constantly, going from "On" to "Off" at short intervals, in the case of the indicator, or from a small charging current to zero, in the case of the ammeter, what does this signify?

A. That the setting of the battery cut-out is very sensitive and that the engine is then running at or about the speed that the instrument should cut-in. Since the speed of an engine varies considerably when running slowly, picking up momentarily and then falling off for a longer period, there is a corresponding variation in the potential, causing the cut-out to operate intermittently. This is a condition that seldom occurs and results in no harm when it does.

Q. When the ammeter or indicator flutters in the same manner with the engine running at medium or at high speed, what does it indicate?

A. That there is a loose connection between the generator and the cut-out, or an intermittent short-circuit or ground caused by a chafed wire alternately making contact with some metal part owing to the vibration. It is much more likely to be simply a loose connection and will be found most often on the back of the cut-out itself. This should be remedied at once. If neglected, it will cause abnormal wear of the platinum points in the cut-out.

Q. When the ammeter does not indicate "Charge" though the engine is speeded up, but does register a discharge when the lights are turned on and the engine is idle, what is the nature of the trouble?

A. Either the generator is not producing current or the regulator (where an external type is employed) is not working properly. The generator brushes may not be making proper contact with the commutator, or there may be a loose, corroded, or broken connection in the generator cut-out battery circuit. Where a belt drives the generator, it may be too loose to run the machine at its proper speed.

Q. When the ammeter gives no charging indication though the lamps are off and the engine is speeded up, and gives no discharging indication though the engine is idle and lamps are switched on, what is likely to be the cause?

A. There is an open or a loose connection in the battery circuit or in the battery itself. The ammeter may be at fault. See that its indicating pointer has not become jammed nor dropped off its bearings.

Q. In case the ammeter indicates "Discharge" though the engine be idle and all lights turned off, what is the trouble?

A. There is a short-circuit or a ground somewhere in the lighting circuits or between the battery and the ammeter, as the discharge reading in such circumstances indicates a leakage of current; or the cut-out has failed to operate and still has the battery in circuit with the generator, though the engine is stopped. The ammeter pointer may be bent.

Q. When the meter indicates a charge though the engine is at rest, what is the nature of the fault?

A. The ammeter pointer has become bent or deranged so that it is stuck fast in place, showing a charge.

Q. When the ammeter charge indications are below normal, what is apt to be the cause?

A. The generator commutator or brushes may need attention, such as cleaning or sanding-in, or new brushes may be necessary. The generator speed may be too low; in case of belt drive, it may not be getting the benefit of the full speed of the engine owing to a slipping belt. The regulator (external type) may not be functioning properly, or there may be an excessive lamp load on the generator.

Q. When the ammeter charge reading is above normal, what is likely to be the cause?

A. There may be a short-circuited cell in the battery, or a short in the charging circuit, or the regulator (external type) may not be working properly.

Q. What will cause the discharge reading of the ammeter to become abnormally high?

A. The lamp load may be excessive, as where higher candle-power bulbs are used, or more lights than originally intended are put in the circuit. There may be leakage in some part of the lighting circuit, or the regulator contacts may be stuck together, permitting a discharge through it or through the generator.

ELECTRIC GEAR-SHIFT

Q. What is the operating principle upon which the electric gear-shifting mechanism is based?

A. That of the solenoid and its attraction for its core when a current is passed through its winding.

Q. What is the source of current supply for the electric gear-shift?

A. The storage battery of the lighting system. The operation of gear-shifting is carried out so quickly that only a nominal additional demand is made on the battery.

Q. How is the electric gear-shift controlled?

A. By a series of buttons corresponding to the various speeds and located on the steering wheel, and by a master switch.

Q. What is the object of the buttons, and what are they termed?

A. To partly close the circuit to the particular solenoid of the speed desired. They are termed "selector switches" since they permit selecting in advance the speed desired.

Q. Why is a master switch employed, and why is it so called?

A. To avoid the complication which would otherwise result from the necessity of providing two switches for each change of speed, i.e., a selector switch and an operating switch. It is termed a master switch because it controls the current supply to all of the circuits.

Q. Why is a neutral button provided in addition to the buttons for the various speeds on the selector switch?

A. To return any of the selector buttons to neutral without the necessity of going through that speed in case it is not desired to engage the speed in question after the button has been pushed. Also

to open any of the selector switches that may be closed when it is desired to stop.

Q. What is the neutralizing device?

A. It is a mechanism incorporated with the shifting mechanism to open the master switch automatically after the gears have been engaged.

Q. Why is the neutralizing device necessary?

A. If it were not provided, the master switch would remain closed, causing a constant drain on the battery and rendering the mechanism inoperative after one shift had been made.

Q. How many solenoids are provided in the standard three-speed and reverse gear box?

A. One for every movement necessary.

Q. Is the current sent through a solenoid in one direction to pull the shifting bar into it and then in the opposite direction to move the bar the other way?

A. No, the current is not reversed through the same solenoid. After the left-hand solenoid, operating the first-speed gear, for example, has pulled the shifter bar to the left, a second solenoid, on the opposite end of the same bar, is energized to pull it back to the right, to shift to second or intermediate. The current is sent through a different solenoid by means of the selector switches for each shift desired.

Q. When the electric gear-shift failed to operate, where would be the most likely place to look for the cause of the trouble?

A. First see that the battery is not exhausted, then that no connections between the battery and the terminal block have parted, thus cutting off the current supply. The wiring is so simple and so strongly protected that it is very unlikely to have anything happen to it except at the connections. This is likewise true of the solenoids.

Q. In case the battery is amply charged and nothing is wrong with the connections, what procedure should be followed?

A. Use the lamp-testing set described in connection with the lighting and starting systems and test out the various circuits as shown on the wiring diagram. In using this test, it must always be borne in mind that touching the two points to the same or connecting pieces of wire or metal will always cause the lamp to light. It is useful in this way for indicating the continuity of a wire, i.e., that it has not

broken under the insulation, but, until experience has been gained in its use, it will be nothing unusual to find that the points have been touched to connecting pieces of metal which have no relation to the circuit. As such metal will complete the circuit through the lamp, the latter will light, but without indicating anything of value to the trouble hunter. Always test the lamp itself before proceeding. It may have become partly unscrewed in its socket or its filament may have been broken.

BATTERY

Electrolyte

Q. Why is it necessary to refill the battery jars at regular intervals?

A. Because the heat generated in the cells evaporates the water from the electrolyte, and, if the latter is permitted to fall below the tops of the plates, they will dry out where they are exposed, and the heat of charging will then cause them to disintegrate, ruining the battery.

Q. Why should this be done at intervals of not less than two weeks?

A. Because the limited amount of electrolyte permitted by the restricted size of the cells over the plates—usually one-half inch—will be evaporated in that period by a battery that is in more or less constant use.

Q. Why should water alone and never acid or electrolyte be used to make up this loss?

A. Only the water evaporates, so that if either acid or fresh electrolyte is added, it will disturb the specific gravity of the solution in the cells and totally alter their condition.

Q. What is the reason that battery manufacturers insist that only distilled water or its nearest equivalent, rain water or melted artificial ice, be used for this purpose?

A. Because ordinary water contains impurities that are apt to harm the plates, such as iron salts, or alkaline salts that will affect both the plates and the electrolyte.

Q. What should be done to a battery that has had its efficiency impaired by being filled with impure water?

A. The cells should be taken apart, the separators discarded, the plates thoroughly washed for hours in clean running water

without exposing them to the air where they would dry, the jars washed out, the plates reassembled with new separators, the jars filled with fresh electrolyte of the proper specific gravity, and the battery put on a long slow charge from an outside charging source, i.e., not on the car itself. Unless there are proper facilities for carrying this out, it will be preferable to ship the battery back to the maker so that it can be given proper treatment, particularly as it is necessary to reseal the cells.

Q. How is electrolyte prepared?

A. By adding pure sulphuric acid a very little at a time to distilled water until the proper specific gravity is reached, and then permitting the solution to cool before using. The mixture must always be made in a porcelain, hard rubber, or glass jar; never in a metal vessel. Commercial sulphuric acid or vitriol should not be employed, as it is far from pure. Never add acid to water. When the two are brought together, their chemical combination evolves a great amount of heat, and the acid will be violently spattered about.

Q. How often should distilled or rain water be added to the cells?

A. This will vary not alone with different systems but with different cars equipped with the same system, owing to the difference in conditions of operation. The only way to determine this definitely is to inspect the cells at short intervals and note how long they will operate before the electrolyte gets close enough to the tops of the plates to require additional water. This may be a week, ten days or two weeks, or even more, if the car is not run much.

Q. When a battery requires the addition of water at very short intervals to keep the level of the electrolyte one-half inch above the plates, what does this indicate?

A. It shows that the battery is being constantly overcharged, which keeps it at a high temperature, causing excessive evaporation. This will usually occur where a car is in constant use during the day but is driven very little at night. It may be remedied by adjustment of the regulation so as to reduce the output of the generator. Where this is not possible, as in the case of simple bucking-coil regulation which is entirely self-contained and permits no variation, additional resistance may be introduced in the generator-battery circuit. This

may take the form of a small-resistance unit consisting of German silver or other high-resistance wire wound on a porcelain tube and mounted on the forward side of the dash. A single-pole knife-blade switch should be placed in the circuit with the resistance so that the latter can be cut in or out of the generator circuit as circumstances may require.

Q. How can the amount of resistance to be inserted in the circuit be figured?

A. By the use of Ohm's law. In this case, it would be $\frac{R}{E}=C$ or resistance divided by voltage equals current. How much resistance to use can only be answered by the conditions of operation. Where a car is used steadily during the day and very seldom at night, it may be necessary to reduce the charge by two-thirds. In the case of a 6-volt system normally charging at 12 amperes, this would require approximately 28 ohms additional, since $\frac{28}{7}=4$ amperes. This is on the assumption that the battery actually receives 12 amperes through the resistance of its original circuit. Seven is used as the voltage, since the generator of a 6-volt system generates current at 7 to 7½ volts in order to overcome the voltage of the battery when fully charged. The amount of resistance wire necessary to give this resistance or any other resistance necessary may be found in tables of wire sizes and resistances of special wire employed for this purpose. The wire is bare and must be wound on the tube so that adjacent coils do not touch. An extreme instance is cited here. It may be necessary in many cases to reduce the charging rate by a very much smaller fraction. Unless trouble of the nature mentioned is experienced, the charging rate should not be altered.

Q. When the battery is constantly gassing, or "boiling", as the car owner usually puts it, what is the trouble?

A. It is being constantly overcharged. This will greatly reduce the life of the battery, and the charging rate should be reduced, as mentioned in the preceding answer. It is essential that the battery be kept fully charged; but if it is continually overcharged, this will keep the cells at an abnormal temperature which is injurious to the plates. The treatment to be given the battery will vary with the season, for the demand upon it is much heavier during cold weather than in summer.

Hydrometer Tests

Q. Why should the battery be tested with the hydrometer at regular intervals of a week or so?

A. Because the specific gravity of the electrolyte is the most certain indication of the battery's condition.

Q. What should the hydrometer read when the battery is fully charged?

A. 1.280 to 1.300.

Q. What point is it dangerous to permit the specific gravity of the electrolyte to fall below, and why?

A. 1.250; because below this point, the acid begins to attack the plates and the battery plates sulphate. The lower the specific gravity, the faster sulphating takes place.

Q. What should be done when the hydrometer reading is 1.250 or lower?

A. The battery should be put on charge immediately, either by running the engine or by charging from an outside source of current until the gravity reading becomes normal.

Q. If the hydrometer reading of one cell is lower than that of the others, what should be done?

A. Inspect the cell to see if the jar is leaking; note whether electrolyte is over the plates to the depth of ½ inch and whether the electrolyte is dirty. If these causes are not apparent, the cell will have to be opened and inspected for short-circuits from an accumulation of sediment in the bottom of the jar or from buckling of the plates.

Q. Are hydrometer tests alone conclusive?

A. No. To be strictly accurate, they should be checked by voltage tests, in addition.

Q. How should these voltage readings be taken?

A. With the aid of a portable voltmeter, using the low-reading scale, i.e., 0-3 volts, and always with the battery discharging, the load not exceeding its normal low discharge rate.

Q. Why should the test not be made with the starting-motor load?

A. Because the discharge rate while the starting motor is being used is so heavy that even in a fully charged battery in good condition it will cause the voltage to drop rapidly.

Q. Why should the voltage readings not be taken while the battery is charging?

A. Because the voltage of the charging current (always in excess of six volts) will cause the voltage of a battery in good condition to rise to normal or above the moment it is placed on charge, such readings are not a good indication of the battery's condition.

Q. What should the voltage of the cells be?

A. In any battery in good condition, the voltage of each cell at the battery's normal low discharge rate (5 to 10 amperes, as in carrying the lamp load) will remain between 2.1 and 1.9 volts until it begins to approach the discharged condition. A voltage of less than 1.9 volts per cell indicates either that the battery is nearly discharged or that it is in bad condition. The same state is also indicated when the voltage drops rapidly after the load has been on a few minutes.

Joint Hydrometer-Voltmeter Test

Q. What should the hydrometer and voltmeter readings be for a fully charged battery in good condition?

A. Hydrometer 1.275 to 1.300; voltage 2 to 2.2 volts per cell.

Q. What does a hydrometer reading of 1.200 or less with a voltage of 1.9 volts or less per cell indicate?

A. This shows that excess acid has been added to the electrolyte. Under these conditions, the lights will burn dimly even though the hydrometer test alone would appear to show that the battery is more than half charged.

Q. What does a hydrometer reading in excess of 1.300 indicate?

A. It indicates that an excessive amount of acid has been added to the electrolyte, regardless of whether the voltage reading is high, low, or normal.

Q. Where a low voltage reading is found, how can it be determined whether the battery is in bad condition or merely discharged?

A. Stop the discharge by switching off the load (lamps) and put the battery on charge, cranking the engine by hand. After a few minutes of charging, note whether the voltage of each cell promptly rises to 2 volts or more. Any cells that do not are probably short-circuited or otherwise in bad condition.

Q. How can a rough test of the condition of the battery be made without the use of any instruments?

A. On systems fitted with a battery cut-out in the generator battery circuit, remove the cover of the cut-out (the generator being stationary) and momentarily close the cut-out points with the finger. The discharge shown by the ammeter the monent the points are closed should be anywhere from 10 to 20 amperes, differing, of course, with different systems. In any case, it should be equal to or greater than the maximum normal output of the generator, provided the battery is at least three-quarters charged.

Q. What effect will allowing the electrolyte to fall too low in the cells have, apart from the damage that it will cause to the plates?

A. It will tend to increase the voltage if the battery is otherwise in good condition, and this may be carried to a point where it will burn out the lamps.

Q. What is meant by "floating the battery on the line"?

A. This describes the relation of the battery to the generator and lighting circuits in systems where the current for lighting is taken directly from the generator when running, any excess over the requirements of the lamps being absorbed by the battery. The moment the generator speed falls below the point where it supplies sufficient current to supply all that is needed for the lamps, the battery automatically supplies the balance. When the generator is idle, the battery, of course, supplies the current for lighting as well as for starting.

Gassing

Q. Why should the cell tops be wiped dry from time to time and the latter as well as the terminals be washed with a weak solution of ammonia and water?

A. As the charge approaches completion, the cells gas; when overcharged they gas very freely. This gas carries with it in the form of a fine spray some of the electrolyte, and the acid of the latter will attack the terminals and corrode them. Wiping clean does not remove this acid entirely, so the ammonia solution is necessary to counteract its effect, the ammonia being strongly alkaline.

Q. Why should an unprotected light, i.e., any flame or spark, not be allowed close to a storage battery?

A. Because the gas emitted by the battery on charge is hydrogen, which is not only highly inflammable but, when mixed in certain proportions with air, forms a powerful explosive mixture.

Q. What is the cause of gassing?

A. When a battery is charged, the water of the electrolyte is decomposed by the current into gases. During the early part of the charge these gases unite with the active material of the plates, but as the charge proceeds, more gas is evolved than the plates can take care of and it bubbles up through the electrolyte. This is known as the gassing point, and the temperature of the cell also begins to rise at that point.

Q. Is gassing harmful to the battery?

A. The greatest wear on the positive plates takes place during the gassing period, and, if carried too far, they may be injured by reaching a dangerous temperature (105° F., or over) which will tend to loosen the active material.

Q. How can gassing be checked?

A. By cutting down the charge. In some systems this can be effected by the insertion of extra resistance provided for the purpose. Where this cannot be done and it is necessary to keep the car running, turn on all the lamps or start the engine once or twice to reduce the charge of the battery. As the lamps usually consume 80 to 95 per cent of the generator output, they should be sufficient to prevent a further overcharge.

Q. Can the generator be disconnected from the battery to prevent overcharge?

A. Not unless it is short-circuited, as directed in the instructions covering different systems. Otherwise, it will blow its field fuse or, where one is not provided, burn out its windings, except in cases where special provision is made to guard against this.

Sulphating

Q. Why must a battery never be allowed to stand in a fully discharged state?

A. Because the acid of the electrolyte then attacks the plates and converts the lead into white lead sulphate which is deposited on them in the form of a hard coating that is impenetrable to the electrolyte, so that the plates are no longer active. The battery then is said to be *sulphated.*

Q. Can a sulphated battery be put in good condition, and what treatment must be given it to do so?

A. If the sulphating has not gone too far, the battery may be brought back to approximately normal condition by a long heavy charge at a higher voltage than ordinary. Where the battery has become badly sulphated, it is preferable to remove it from the car and charge from an outside source of current, as it may require several days to complete the process. (Note instructions regarding the running of the generator when disconnected from the battery, as otherwise it may be damaged.) If avoidable, the car should not run with the battery removed. If the battery has not stood discharged for any length of time, the charge may be given on the car by running steadily for 8 to 10 hours with all lights off. No lamps must be turned on, as the increased voltage is liable to burn them out.

Voltage Tests

Q. What is the purpose of the voltmeter in connection with the battery?

A. It is chiefly useful for showing whether a cell is short-circuited or is otherwise in bad condition.

Q. Can the voltmeter alone be relied upon to show the condition of the cells?

A. No; like the hydrometer, its indications are not always conclusive, and it must be used in conjunction with the hydrometer to insure accuracy.

Q. What type of voltmeter should be employed for making these tests?

A. For garage use, a reliable portable instrument with several connections giving a variable range of readings should be employed. For example, on the 0-3 volt scale, only one cell should ever be tested; attempting to test any more than this is apt to burn out the 3-volt coil in the meter. The total voltage of the number of cells tested should never exceed the reading of the particular scale being used at the time, as otherwise the instrument will be ruined.

Q. Must these readings be particularly accurate?

A. Since a variation as low as .1 volt (one-tenth of a volt) makes considerable difference in what the reading indicates as to the condition of the battery, it will be apparent that the readings must not only be taken accurately, but that a cheap and inaccurate voltmeter is likely to be misleading rather than helpful.

Q. What precautions should be taken before using the voltmeter?

A. Always see that the place on the battery connector selected for the contact is bright and clean and that the contact itself is firm, otherwise the reading will be misleading since the increased resistance of a poor contact will cut down the voltage.

Q. How is the instrument connected to the battery?

A. The positive terminal of the voltmeter must be brought in contact with the positive terminal of the battery and the negative terminal of the voltmeter in contact with the negative terminal of the battery.

Q. In case the markings on the battery are indistinct, how can the polarity be determined?

A. Connect the voltmeter across any one cell. Should the pointer not give any voltage reading, butting against the stop at the left instead, the connections are wrong and should be reversed; if the instrument shows a reading for one cell, the positive terminal of the voltmeter is in contact with the positive terminal of the battery. This test can be made without any risk of short-circuiting the cell, since the voltmeter is wound to a high resistance and will pass very little current. Such is not the case with the meter, which should never be used for this purpose.

Q. When the battery is standing idle, what is the cell voltage and why is this not a good test?

A. Approximately two volts, regardless of whether the battery is fully charged or not. Voltage readings taken when the battery is on open circuit, i.e., neither charging nor discharging, are only of value when the cell is out of order.

Q. If the battery is in good condition and has sufficient charge, what should the voltmeter reading show?

A. Using the lamps for a load, the voltage reading after the load has been on for five minutes or longer should be but slightly lower (about .1 volt) than if the battery were on open circuit.

Q. When one or more cells are discharged, what will the reading show?

A. The voltage of these cells will drop rapidly when the load is first put on and sometimes even show reverse readings, as when a cell is out of order.

Q. What will the voltmeter indicate when the battery is nearly discharged?

A. The voltage of each cell will be considerably lower than if on open circuit after the load has been on for five minutes or more.

Q. How can the difference be distinguished between cells that are merely discharged and those that are in bad condition?

A. Put the battery on charge, cranking the engine by hand to start, and test again with the voltmeter; if the voltage does not rise to approximately 2 volts per cell within a short time, it is evidence that there is internal trouble which can be remedied only by dismantling the cell.

Q. What effect has the temperature on voltage readings?

A. The voltage of a cold battery rises slightly above normal on charge and falls below normal on discharge. This last is one of the chief reasons for its decreased efficiency in cold weather.

Q. What is the normal temperature of the battery and to what does this refer?

A. The normal temperature of a battery is considered at 70° F., but this refers to the temperature of the electrolyte in the battery as shown by a battery thermometer and not to the temperature of the surrounding air. If the battery has been charging at a high rate for some time, it may be normal even though the weather be close to zero at the time.

Sediment

Q. What is the cause of sediment or mud accumulating in the jars, and why must it be removed before it reaches the bottoms of the plates?

A. This sediment consists of the active material of the plates, which has been shaken out, due to the loosening caused by the charging and discharging, and aggravated by the constant vibration. It must never be allowed to reach the plates, as it is a conductor and will short-circuit them and thus ruin the battery.

Q. How long will a battery stay in service before this occurs?

A. This depends on the type of jar employed and the treatment that the battery has received. If it has been kept constantly overcharged, or if discharged to exhaustion in a very short period, as by abuse of the starting motor when the engine is not in good

starting condition, or if it has been subjected to short-circuits by grounding or by dropping tools on its terminals, the plates will disintegrate much quicker than where proper treatment has been given it. With the old-style jar, only an inch or so is allowed to hold this accumulation of sediment below the plates, while in later types fully 3 inches or more are allowed in the depth of the cell for this purpose. A battery with jars of the latter type that has been cared for properly should not require washing out under two years. The procedure is the same as that given for removing the effects of impure water. The plates must never be allowed to dry.

Washing the Battery

Q. What is meant by washing the battery, and why is it necessary?

A. Washing a battery involves cutting the cells apart, washing the elements and the jars, and reassembling with new separators and new electrolyte. It is necessary to prevent the accumulation of sediment, consisting of active material shaken from the plates, to a point where it will touch them and thus cause a short-circuit.

Q. How often is it necessary to wash a battery?

A. This will depend on the type of cell in the battery and the age of the latter. If the battery has the modern-style jar with extra deep mud space, it probably will not be necessary to wash it until it has seen two to three seasons' use. With the older form of cell in which the space allowed for sediment is much less, washing doubtless will be necessary at least once a season. As the battery ages, it will be necessary to wash it oftener.

Q. What other causes besides the type of jar and the age of the battery influence the frequency with which it is necessary to wash the battery?

A. The treatment the battery has received. If it has been abused by overcharging and permitting the cells to get too hot, the active material will be forced out of the grids much sooner.

Q. How can the necessity for washing be determined?

A. The presence of one or more short-circuited cells in a battery that has not been washed for some time will indicate the necessity for it. Each cell should be tested separately with the low-reading voltmeter; a short-circuited cell will either give no

voltage reading or one much below that of the others. Cut such a cell out and open it; if the short-circuit has been caused by an accumulation of sediment, the others most likely are approaching the same condition.

Q. How is a battery washed?

A. By cutting the cells apart, unsealing them, and lifting out the elements which should be immersed immediately in a wooden tub of clean pure water. The separators then are lifted out and the positive and negative groups of plates separated, but they must be marked so that the same groups may go back in the right cells. Before disposing of the old electrolyte, its specific gravity should be noted, as new electrolyte of the same density must be used. The plates should be washed in copious running water for several hours, but their surfaces must never be exposed to the air. Reassemble with new separators, fill the jars with fresh electrolyte of the same specific gravity as that discarded, and keep the elements under water until ready to place in the jars, which then should be sealed and the lead connectors burned together again.

Give a long slow charge after reassembling. The battery will not regain its normal capacity until it has been charged and discharged several times.

Connectors

Q. Why should lead connectors be employed, and why is it necessary to burn them together?

A. Any other metal will corrode quickly. Burning is necessary to make good electrical connection, except where bolted connectors are employed.

Q. When connections have become badly corroded or broken, what should be done with them?

A. They should be replaced with new lead-strap connectors supplied by the makers. If they are not obtainable and the battery must be in service meanwhile, the old ones can be cleaned by cutting away the corroded parts and burning new lead on them to bring them to normal size. If broken, burn together with lead in the same way. Heavy copper cable can be used temporarily but must be removed as soon as possible, as it will corrode quickly. Never use any other metal except lead or copper and never use light copper

wire. It will either be burned up in a flash or it will cut down the amount of current from the battery, thus causing unsatisfactory operation.

Buckled Plates

Q. What is the cause of badly disintegrated or buckled plates?

A. Sudden discharge due to a short-circuit or to constant abuse of the starting motor on an insufficiently charged battery.

Q. Is there any remedy for such a condition?

A. If the plates are not badly buckled and have not lost much of their active material, the cells may be put in service again by washing and reassembling as described, but if there is any considerable loss of active material, new plates will be necessary.

Low Battery

Q. What are the indications of a low battery?

A. The starting motor fails to turn the engine over, or does so very slowly, or only a part of a revolution. The lights burn very dimly. The hydrometer shows a specific-gravity reading of 1.250 or less. Voltmeter test shows less than 5 volts for a 3-cell battery (for greater number of cells, in proportion), or 1.75 volts or less for each cell.

Q. What are the causes of a low battery?

A. The electrolyte not covering the plates, or being too weak or dirty. A short-circuit in the battery due to the accumulation of sediment reaching the bottom of the plates. An excessive lamp load, all lights being burned constantly with but little daylight running the car. Generator not charging properly.

Specific Gravity; Voltage

Q. What are the specific gravity and voltage of fully discharged and fully charged cells?

A. Total discharge: 1.140 to 1.170 on the hydrometer; and 1.70 to 1.85 volts on the voltmeter. Fully charged: 1.276 to 1.300 specific gravity; 2.35 to 2.55 volts.

Q. Are these readings always constant for the same conditions?

A. No. The charging voltage readings will vary with the temperature and the age of the cell; the higher the temperature and the older the cell the lower the voltage will be. Hydrometer

readings also depend on the temperature to some extent. For every ten degrees Fahrenheit rise in temperature, the specific gravity reading will drop .003 or three points, and *vice versa*.

Q. Under what conditions should voltage tests be made?

A. Only when the battery is either charging or discharging. Readings taken when the battery is idle are of no value.

Q. Under what conditions should hydrometer tests be made?

A. The electrolyte must be half an inch over the plates and it must have been thoroughly mixed by being subjected to a charge. Hydrometer readings taken just after adding water to the cells are not dependable.

Q. When should acid be added to the electrolyte?

A. As the acid in a battery cannot evaporate, the electrolyte should need no addition of acid during the entire life of the battery under normal conditions. Therefore, if no acid has leaked or splashed out and the specific gravity is low, the acid must be in the plates in the form of sulphate and the proper specific gravity must be restored by giving the battery an overcharge at a low charging rate.

Q. What does a specific gravity in some cells lower than in others indicate?

A. Abnormal conditions, such as a leaky jar, loss of acid through slopping, impurities in the electrolyte, or a short-circuit.

Q. How can it be remedied?

A. Correct the abnormal conditions, and then overcharge the cells at a low rate for a long period, or until the specific gravity has reached a maximum and shows no further increase for 8 or 10 hours. If, at the end of such an overcharge, the specific gravity is still below 1.270, add some specially prepared electrolyte of 1.300 specific gravity. Electrolyte should not be added to the cells under any other conditions.

Q. Is an overcharge beneficial to a battery?

A. The cells will be kept in better condition if a periodical overcharge is given, say once a month. This overcharge should be at a low rate and should be continued until the specific gravity in each cell has reached its maximum and comparative readings show that all are alike. To carry this out properly will require at least 4 hours longer than ordinarily would be necessary for a full charge. If the plates have become sulphated due to insufficient

charging, it may be necessary to continue the overcharge for 10 to 15 hours longer. Should the specific gravity exceed 1.300 at the end of the charge, draw off a small amount of electrolyte with the syringe from each cell and replace with distilled water. If below 1.270, proceed as mentioned above for addition of acid.

Charging from Outside Source

Q. What is meant by charging from an outside source?

A. A source of direct current other than the generator on the car.

Q. Why is it necessary to charge the battery from an outside source?

A. When the battery has become sulphated, has been standing idle for any length of time, or has been run down from any other cause so that it is out of condition, a long charge at a uniform rate is necessary, and it would seldom be convenient to run the car for 8 or 10 hours steadily simply to charge the battery; frequently, a longer charging period than this is necessary.

Q. How is charging from an outside source effected?

A. This will depend upon the equipment at hand and the nature of the supply, i.e., whether alternating or direct current. If the current is alternating, a means of converting it to direct current is necessary, such as a motor-generator, a mercury-arc rectifier, chemical or vibrating type of rectifier. These are mentioned about in the order of the investment involved. In addition, a charging panel is needed to complete the equipment, this panel being fitted with switches, voltmeter, and ammeter, and a variable resistance for regulating the charge. Where direct-current service is obtainable at 110 or 220 volts, the rectifier is unnecessary.

Q. How can a battery be charged from direct-current service mains without a special charging panel?

A. By inserting a double-pole single-throw switch and 10- or 15-ampere fuses on taps from the mains and ordinary incandescent lamps in series with the battery to reduce the voltage, Fig. 480.

Q. How many lamps will be needed?

A. This will depend upon their character and size, as well as upon the amount of charging current necessary. For a 10-ampere charge for a 6-volt storage battery, seven 110-volt 100-watt (32

c.p.) carbon-filament lamps, or their equivalent, will be needed; i.e., fourteen 110-volt 50-watt (16 c.p.) carbon-filament lamps; eighteen 110-volt 40-watt tungsten lamps, or twenty-eight 110-volt 25-watt tungsten lamps. For a 12-volt or 24-volt battery the number of lamps will have to be decreased in proportion in order not to cut the voltage of the supply current below that of the battery. For 220-volt d.c. supply mains, if a three-wire system is employed, the taps should be taken from the center wire and one outside wire; this will give 110 volts. If the service is 220-volt two-wire, more lamps will be needed to reduce the voltage, which should exceed that of the battery by only 1½ to 2 volts, except where a high voltage charge to overcome sulphating is being given, in which case it may be slightly higher.

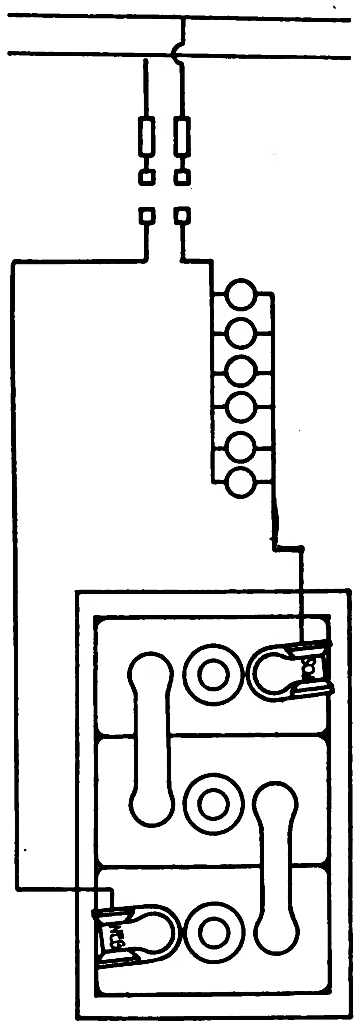


Fig. 480. Diagram of Connections for Charging Six-Volt Storage Battery from Lighting Circuit

Q. Where no outside source of current is available, or where no rectifier is at hand to convert alternating current, how can the battery be given the long charge necessary?

A. Run the engine. Supply it with plenty of oil and provide hose connections from the water supply to the filler cap on the radiator and a drain from the lower petcock. Open the latter and turn on just sufficient water to keep the engine reasonably cool; increase if necessary as it runs hotter.

Q. What precaution must be taken always before putting the battery on charge from an outside source?

A. The polarity of the circuit must be tested in order to

make certain that the battery will be charged in the proper direction.

Q. How can this be done?

A. If a suitable voltmeter is at hand, i.e., one of the proper voltage for the 110-volt current, connect it to the mains. If the needle does not move over the scale but shows a tendency to butt against the stop pin at the left, reverse the connections. The needle will then give a proper reading and the positive connection to the meter must be used for the positive side of the battery. Should no voltmeter of the right voltage be available, connect two short wires with bared ends to the fused end of the switch. Dip the bared ends of the wire in a glass of water, being careful to keep them at least an inch apart. When the switch is closed, fine bubbles will be given off by the wire connected to the negative side. The battery terminals are stamped *Pos.* and *Neg.*, and the connections should be made accordingly.

Intermittent and Winter Use

Q. What should be done with an idle battery?

A. If it is to be idle for any length of time, as where the car is to be stored, it should be given a long overcharge as described above before being put out of service. Fill the cells right to the top with distilled water to allow for evaporation and absorption of acid by the plates. Give the battery a freshening charge at a low rate once a month. Discharge the battery and re-charge before putting it into service again. If it has stood out of service for a long period, the battery will be found at a low efficiency point and will not reach its maximum capacity again until it has had several charges and discharges.

Q. Does cold weather have any effect on the storage battery?

A. It causes a falling off in its efficiency. If not kept charged, the electrolyte will freeze under the following conditions: battery fully discharged, sp. gr. 1.120, 20° Fahrenheit; battery three-quarters discharged, sp. gr. 1.160, temperature zero; half discharged, sp. gr. 1.210, 20 degrees below zero; one quarter discharged, sp. gr. 1.260, 60 degrees below zero. When storing away for the winter, the battery must either be kept charged or put where the temperature does not go lower than 20 degrees above zero.

Edison Battery

Q. Is it ever necessary to wash out an Edison battery?

A. No. The cells are permanently sealed, as the active material cannot escape from its containers.

Q. Do all of the foregoing instructions apply to the Edison as well as to the lead-plate battery?

A. No. The Edison requires very little attention, practically the only care necessary being to keep the cars replenished with distilled water at intervals.

Charging rates for Edison cells are given on pages 97 and 98, Electric Automobiles. S.A.E.-standard instructions for lead-plate cells are given on pages 138-140, Electric Automobiles.

MOTORCYCLES

INTRODUCTION

Evolution of the Motorcycle. The same period which has brought the automobile to its present state of perfection has also witnessed the birth and development of the motorcycle. This two-wheeled motor vehicle was developed from the bicycle; in fact, the first motorcycles were bicycles with motors attached. However, owing to the comparatively high speed attained, the strains put upon the bicycle frame were too great, and extensive modifications were carried out, which resulted in a distinctive design and construction to stand the requirements of the service. It is significant of the general improvement in the construction that several motor bicycles have recently been designed and are giving good service.

The motorcycle started entirely as a pleasure, or sporting, vehicle, used by a few bicycle enthusiasts who desired greater speed or by racing men for pacemaking. Gradually, however, the utility of the machine in many directions became established, and now its place in its own field is as surely fixed as that of the automobile itself. For single or tandem road work, for package delivery, for messenger service, for military duty, and for a hundred other important offices, it is unexcelled, and the thousands upon thousands of machines that are sold every year in this country alone bear testimony to its popularity. There are other indications in some recently developed types that the field of usefulness of this flexible machine will be broadened still further.

Standard Specifications. The conventionalized American motorcycle is of two-cylinder construction. The frame is tubular and diamond shaped, with a double crossbar at the top, between which bars are located a gasoline tank and an oil tank. At its lowest point the frame is in the form of a loop, in which is clamped the aluminum crankcase of a twin-cylinder air-cooled motor, with the cylinders set V-shaped and a carburetor fitted between. Separate exhaust pipes lead from each cylinder to a muffler. The motor is of the L-head type, with the cylinders, as a rule, cast in one piece. The exhaust

valves are at one side of the motor and are operated by cams on the lower side of the crankcase. The same cam often operates both exhaust valves.

In a removable cage on the roof of the valve pocket just over the exhaust valve, is located the intake valve, which is operated by a rocker arm above it, controlled by a push rod running up the side of the motor from the cam case. The crankcase contains two flywheels, which form also the crank arms of a built-up crank. Both connecting rods are fastened to the same crankpin, and these rods run down between the flywheels.

In the cam case is a small plunger oil pump which pumps oil in small quantities to the forward cylinder, this oil being delivered through the wall of the cylinder directly onto the piston at the lower end of its stroke. From this point the oil drops into the crankcase and is thrown up through the rest of the motor by the splash system. The crankshaft on one side runs into the cam case, from which a train of gears drives a magneto for ignition. The advance and the retard of this magneto are controlled by twisting one of the handlebars of the motorcycle, this motion being ordinarily transmitted to the magneto through a series of bell cranks and rods. The throttle is controlled by twisting the opposite handlebar; so the control of the entire machine is always within the driver's grasp.

The right end of the motor shaft projects beyond the right side of the case and ends in a small roller-chain sprocket, from which a chain runs to a larger sprocket on a countershaft set at the base of (or just back of) the vertical frame-tube member. Since change-speed gearsets are becoming common, this shaft is generally located back of the seat-post tube. The large countershaft sprocket connects with a small countershaft sprocket or with a gearset by means of a multiple-disc friction clutch, either of the dry fabric-faced type or of the metal type. This clutch may be operated by a lever in front of the driver's seat or by a foot pedal or by both. From the countershaft, a chain runs from a smaller sprocket to a larger sprocket on the rear wheel hub of the motorcycle. In this hub is located a brake (or brakes) of the expanding or contracting type or of both, operating on a brake drum. The rear end of the frame is often mounted on springs from the seat-post back, the lower frame forks being pivoted and the upper connection sprung. Within this triangle and generally back of

the seat post is fitted a tool box, while over the wheel a luggage carrier forms the stock equipment. A stand is always fitted on the rear wheel to enable one to leave the motorcycle without its falling over.

The saddle is very large, as compared with a bicycle seat, and has sensitive springs, as well as being mounted usually in a spring-seat post located in the vertical-tube member. This saddle is always placed as low as possible on the frame. The front forks are mounted on some sort of springs—generally of the flat-leaf type—in order to absorb the shocks and thus avoid metal fatigue in the machine as well as bodily fatigue in the rider. This, in outline, is the American motorcycle of today.

Present Trend of Models. This outline is that of what might be called the American heavy-duty motorcycle. About 1914 or 1915, it looked as if this twin-cylinder type, with a change-speed mechanism, would soon displace all other designs. Later developments, however, have brought out several decidedly light-weight machines and at least two motor wheels, so that for 1917 there are more types than ever before. One set of riders has been demanding greater power and greater comfort in each season's models, until we have the expensive high-powered three-speed electric-lighted machines, suitable for all kinds of cross-country work; another class has been clamoring for a light machine of minimum cost both for initial price and for up-keep. These light machines are, of course, limited to city work and other more or less ideal conditions, but they are meeting the want of a large class of buyers. Many of the designs are very similar to the experimental machines developed abroad in the last few years preceding the war.

HISTORY

Early Machines. The first motorcycle built was the work of Gottlieb Daimler, who in 1885 built a two-wheeled vehicle to try out a gasoline motor with which he was experimenting. This machine was the forerunner not only of the motorcycle but of the automobile as well. De Dion of France, with Karl Benz of Germany, developed along with the automobile the gasoline motor, and the De Dion type was soon applied to a motor tricycle, followed by a motor bicycle using the same motor.

This motor was the predecessor of the motorcycle motor of today. The cylinder arrangement and the location of the compression

chamber were almost identical. Two flywheels were used, with a connecting rod between, and the flywheels were entirely enclosed in the crankcase. Viewed in the light of modern design, the motor was very crude but developed horsepower enough to drive this early machine at what was then considered an astonishing speed—30 miles per hour.

The foreign machines were developed between 1894 and 1898, when an American inventor, who had been building racing bicycles, took up the motor-driven tandem as a pace-making mount for bicycle racing. As the motorcycle is all wheel base and no tread, it has no difficulty in holding the road at any speed; a fact which made it very adaptable to this kind of service. The transmission of this machine, designed by Oscar Hedstrom, was the basis of the formation of a company for the manufacture of motor bicycles, with George M. Hendee as the business manager of the concern. At about the same time, the Thomas, the Holly, the Orient, and the Mitchell motorcycles were being developed.

Two-Cylinder Motors. Glenn Curtiss was one of the first to develop a two-cylinder motor. It was in connection with his experiments with motors that he built a motorcycle equipped with an eight-cylinder V-type motor, which, covering a mile in 26.4 seconds—the fastest mile ever covered by man—held the record until recent date.

The first motors built were small-power engines of about the same stroke as bore; they attained surprising speed and cooled very successfully with flanges of small area.

Starting with 2.5-horsepower motors, power and weight were continually added until motors of 12- and even 14-horsepower have become common practice. The latter are, for the most part, of large bore and of comparatively slow speed, but, through the activity of European developments, light-weight machines with high-speed motors are coming into prominence.

Influence of High-Speed Motors. In the early days, when materials and workmanship were questionable except at a great expense, high speed in a motor was a disadvantage and tended toward short life. Belt drive from the motor to the rear wheels was common, and hence motors could not be geared below a certain ratio without having the belt pulley too small to transmit the power. Flat belts became very popular in America and were used on such machines as

the Excelsior, the Harley-Davidson, the Yale, etc., while the Reading-Standard and the Indian factories consistently held to chain drive. Within the past few years, with the introduction of change-speed gears and high-speed motors, a positive drive has become a necessity, and chain drive with reduction to a countershaft located between the motor and the rear wheel has become almost standard practice. Foreign designers still favor the belt to transmit the power from the countershaft to the rear wheel, claiming that this gives greater flexibility of drive. American makers obtain smoothness of action by incorporating a slipping clutch in the transmission.

Light-Weight Machine. First to bring into prominence the light-weight motorcycle and high-speed motor was the Douglas Company, of England, which built a small horizontal-opposed two-cylinder air-cooled motor—a success above 4000 r.p.m. by virtue of its almost perfect balance of moving parts. This motor was set fore-and-aft in a light frame, with a chain taking the power from the motor to a countershaft at the frame junction below. A V-type pulley was the front member of the belt-driven system, and the gear reduction of the first chain drive threw a minimum strain on the belt and hence proved very reliable. This machine weighed, complete, about 183 pounds, and yet it was capable of the same road performance as the high-power American machines of greater weight.

In developing the new series of light-weight machines, already mentioned, the American designers have undoubtedly been influenced by the English successes along these lines. The single cylinder has been retained, and the two-cylinder opposed engine is coming rapidly to the front.

Modern Improvements. While the light machines have been developing, the refinement of the standard twin V-type has gone steadily on. The greatest improvements of recent date have been toward making the motorcycle more comfortable, cleaner, easier to operate, more reliable, and more foolproof. This, in nearly every case, has meant an increase in cost rather than a decrease, but buyers prefer a completely equipped machine at higher prices to partially developed mounts at lower figures. Four-cylinder machines are becoming popular with each succeeding year, and the manufacturers are also incorporating three-speed gearsets, self-starting systems, and other automobile features to as great an extent as possible.

With the many improvements in construction, convenience, and reliability in the motorcycle has come a broadening of its field of usefulness. Fitted with a sidecar and with an extra wheel, it has become the family carryall or has been utilized for city runs and delivery purposes. In the recent wars, motorcycles have played a very important part in the transmission of messages and in the quick dispatch of repair men and scouts for emergency service. A number of the sidecar vehicles have even been fitted with machine guns and very successfully used for rapid reconnoissance work.

TYPES OF MOTORCYCLES

Smith Motor Wheel. Although not a motorcycle in itself, the Smith Motor Wheel for attachment to bicycles has added hundreds of

Fig. 1. Smith Motor Wheel Attached to Rear of Bicycle
Courtesy of A. O. Smith Corporation, Milwaukee, Wisconsin

enthusiasts to the motorcyclist family. This wheel is a self-contained power plant consisting of a single-cylinder four-cycle air-cooled engine, having a bore of $2\frac{3}{8}$ inches and a stroke of $2\frac{1}{4}$ inches.

The engine is carried upon a bed which is flexibly attached to the bicycle frame, the motor wheel following slightly behind the rear

Fig. 2. Four-Wheel Buckboard with Smith Motor Wheel Attached
Courtesy of A. O. Smith Corporation, Milwaukee, Wisconsin

wheel of the bicycle, as shown in Fig. 1. One end of the engine crank-shaft carries the flywheel, while the other end is geared internally to

the driving wheel. The effect of this attachment is very much the same as that of the person running along the side of a bicycle rider and pushing him by means of the seat post, the connection between the motor wheel and the bicycle being quite flexible. This motor wheel has been adapted to all kinds of service, such as light delivery

Fig. 3. Rear of A. O. Smith Buckboard

vans and children's automobiles. The Smith Company has recently brought out a very light four-wheeled buckboard, Fig. 2, carrying two passengers and driven by the motor wheel. The rear connection of this model is shown in Fig. 3.

Dayton. Using the same construction of power plant, the Davis Sewing Machine Company has developed the Dayton Motor Bicycle, which has a motor wheel suspended between the front forks in place

Fig. 4. Dayton Motor Bicycle Showing Power Plant in Front Wheel
Courtesy of Davis Sewing Machine Company, Dayton, Ohio

Fig. 5. Engine Side of Merkel Motor Bicycle
Courtesy of Merkel Motor Wheel Company, New York City

of the ordinary front bicycle wheel, Fig. 4. The illustration also indicates the location of the gasoline tank on the handlebars.

Merkel. Newest in the motor-wheel development is the design of Joseph F. Merkel, who is well known in the motorcycle world through the success of the Merkel Flyer. This Merkel motor wheel is a combination of single-cylinder engine and rear bicycle wheel.

Fig. 6. Flywheel Side of Merkel Motor Bicycle
Courtesy of Merkel Motor Wheel Company, New York City

The engine is on one side of the wheel, Fig. 5, and the flywheel and magneto is carried on the other side, Fig. 6. The whole assembly is intended to replace the rear wheel of an ordinary bicycle, Fig. 7.

Cyclemotor. Besides this crop of motor wheels and of motor-wheel applications, there has appeared again a group of engines to be attached to the frame of the bicycle, driving through a belt to a pulley

added to the rear wheel. Some years ago the same idea was attempted, but, owing to mechanical imperfections, did not seem to be successful. The big advance, however, which has been made in the design

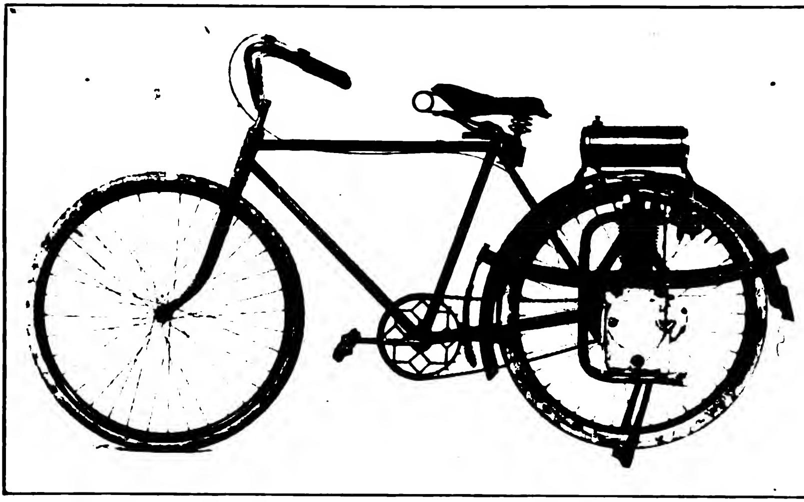


Fig. 7. Complete View of Merkel Motor Bicycle

Fig. 8. Side View of Cyclemotor with Belt Drive
Courtesy of Cyclemotor Corporation, Rochester, New York

and construction of small gasoline engines and in the accessories employed with them, bids fair to make a success of these newer developments; in fact, some of them have been on the market long

enough to have made a favorable impression already. A good example of this type of machine is the cyclemotor, illustrated in Fig. 8.

Auto-Ped. It would be hardly fair to leave this crop of near motorcycles without mention of the Auto-Ped, which is a device on two wheels, with a small board between, and with an engine attached to the front wheel. The operator stands upon the board between the two wheels, as on a child's coaster, and controls the device through a handle which takes care of the steering.

Light-Weight Motorcycles. No attempt will be made to describe or to even list all the light-weight machines that are now on the market. Short descriptions, however, will be given of the machines which are representative of a certain type of construction. In relation to the light-weight movement, the two-cycle engine has come back into striking prominence.

Fig. 9. Excelsior Light-Weight Motorcycle
Courtesy of Excelsior Motor Manufacturing and Supply Company, Chicago, Illinois

Excelsior. One of the best examples of the two-cycle engine is the Excelsior Light-Weight model, Fig. 9, which employs a single-cylinder two-cycle engine of $2\frac{17}{64}$-inch bore and $2\frac{3}{4}$-inch stroke, giving a piston displacement of 22.87 cubic inches. The ignition is provided for by a high-tension magneto driven by a silent chain, and the drive is through a two-speed gear and V-belt. The ratio on high speed is $5\frac{7}{16}$ to 1 and on low speed $8\frac{11}{16}$ to 1. This design shows well-developed springing and a kick starter.

Indian. Of the two-cylinder opposed chains the Indian Light Twin, Fig. 10, is among the most interesting. The cylinders lie fore-

and-aft at the bottom of a very large loop in the frame and are air cooled. The bore is 2 inches and the stroke is 2½ inches, giving a total

Fig. 10. Indian Two-Cylinder Opposed Light-Weight Motorcycle
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

piston displacement of 15.7 cubic inches. The Dixie magneto is mounted directly over the crankshaft. A three-speed sliding-gear

transmission, and a dry-plate clutch deliver the power to the final roller-chain drive.

Thor. While cost of purchase and of upkeep have undoubtedly been the leading factors in developing these light-weight machines, lightness, for its own sake, has a strong appeal to a large class of riders, and the Thor line includes a light twin of the V-cylinder construction, Fig. 11, in which low purchase cost does not enter into consideration. This machine has cylinders with a $2\frac{3}{4}$-inch bore and a $3\frac{1}{4}$-inch stroke, or a total displacement of 38.6 cubic inches, and is provided with a high-tension magneto and with all the other refinements of its brother Thor machines of double the horsepower.

Fig. 11. Thor Light-Weight Motorcycle
Courtesy of Aurora Automatic Machinery Company, Chicago, Illinois

Developments in Standard Types. *Two-Cylinder*. So much for the general types representative of the new light-weight high-speed engine movement. Turning to the more standard American machines, we find no radical changes in the twin-cylinder V-models or in the four-cylinder machines. There are, however, the usual improvements and refinements, with a seeming tendency to decrease the number of models by discarding the two-speed gear and standardizing

the three-speed type. This is probably owing to the fact that every machine sold is more than liable to have a sidecar, a rear car, or some other kind of a car or freight-carrying attachment placed upon it, and the three-speed machine has now been developed to a point where it can adequately take care of this kind of service—a demand which, a few seasons ago, the makers were inclined to feel was an abuse. Fig. 12 shows the latest of the Harley-Davidson Twins, the engine having a bore of $3\frac{5}{16}$ inches and a stroke of $3\frac{1}{2}$ inches, which gives it a piston displacement of 53.55 cubic inches. The dry-plate clutch,

Fig. 12. Harley-Davidson Standard Twin-Cylinder Three-Speed Motorcycle
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

the three-speed transmission, the kick starter, and other features are not new, the only changes being slight refinements, which each season brings about.

In passing, it should not be forgotten that the large single-cylinder type, which was the predecessor of the V-type, is still on the market, although its demise was predicted several seasons ago. This is because a number of large public-service corporations have found this type so successful in their trouble departments that they insist upon purchasing more of them each season. The wide-awake companies, however, are beginning to look more favorably upon the twin-

Fig. 13. Henderson Four-Cylinder Motorcycle
Courtesy of Henderson Motorcycle Company, Detroit, Michigan

cylinder three-speed machines for their heavy service, and there is no question but that the large slow-speed single-cylinder type will in time drop out of sight.

Four-Cylinder. The Henderson Motorcycle Company, of Detroit, has been the successful champion of the four-cylinder design, Fig. 13. These engines are air cooled and have a bore of $2\frac{1}{2}$ inches and a stroke of 3 inches, giving a piston displacement of 58.9 cubic inches. The Henderson has been on the market for several years, and the construction in the past has included a bevel gear at the rear of the crankshaft, which drove through a chain to a planetary two-speed transmission incorporated in the rear hub. For the coming season,

Fig. 14. Side View of Militaire Four-Cylinder Motorcycle
Courtesy of Militaire Motor Vehicle Company, Buffalo, New York

this construction has been replaced by a three-speed sliding gear at the rear of the crankshaft, with a chain drive back to the standard types of hub and band brakes. One of the features of the four-cylinder machine is its very rapid acceleration, which makes it very easy to handle in traffic—excellent for police-department work.

Another four-cylinder machine, the Militaire, has recently been announced, which is illustrated in Fig. 14. This carries an engine of $2\frac{11}{16}$-inch bore and 3-inch stroke, with a piston displacement of 68 cubic inches. The specifications list such unusual features as a selective sliding-gear shaft having three speeds forward and a reverse, which forms a unit with the engine. The drive is by propeller shaft,

Fig. 15. Rear View of Militaire Motorcycle, Showing Auxiliary Wheels in Position for Supporting Motorcycle
Courtesy of Militaire Motor Vehicle Company, Buffalo, New York

and the wheels are of artillery rather than wire type. In Fig. 15 it will be noted that there are two auxiliary wheels which swing up off the ground; in their normal position, they lie at each side of

the rear wheel. These auxiliary wheels are lowered, as shown in the figure, when the machine is left standing or when it is driven in very slow heavy traffic where the motorcyclist so often has to drag his feet upon the ground.

ANALYSIS OF MOTORCYCLE MECHANISMS

Nomenclature. Before going on with a discussion of engines and how to take care of them, it is best to make sure that the reader under-

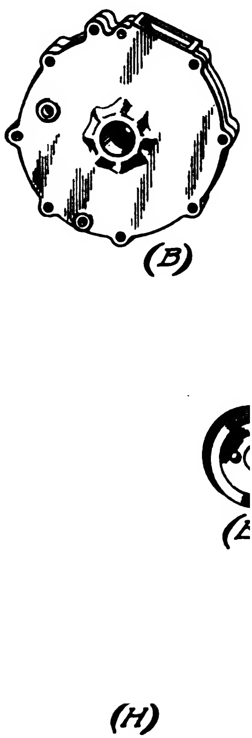


Fig. 16. Diagrams of Various Parts of Motorcycle

stands the names and purposes of the various parts that go to make up the complete machine. When dealing with the principles of the internal-combustion engine, we always deal with the single-cylinder type for the sake of simplicity, pointing out that in the two-cylinder

and four-cylinder engines there has been but a combination of several single-cylinder engines.

Referring to Fig. 16, we have at *A* the cylinder casting, which is made of gray cast iron, although in some cases it does not look it, owing to methods of sand blasting, enameling, etc. The cooling ribs are cast integral and are not of a different material shrunk on as was tried on some air-cooled automobile engines. At *B* is the crankcase, which is an aluminum casting, usually highly polished. Most automobile crankcases are split along a horizontal plane, but the motorcycle crankcase is divided in the verticle plane and bolted together as shown. Piston, connecting rod, and flywheel assembly is shown at *C*. The piston moves up and down in the bore of the cylinder. It is usually made of cast iron and often drilled with a number of comparatively large holes to decrease its weight and also to assist in the lubrication of the cylinder wall. Aluminum is gaining in favor as a piston material because of its light weight. The purpose of the connecting rod is to change the back and forth, or reciprocating, motion of the piston into rotary motion at the crankshaft. This means that there are bearings at both ends. At the upper end, the bearing is called the wrist-pin bearing, because the small shaft across the piston is called the wrist pin. At the lower end, the bearing is known as the connecting rod bearing and the big end bearing.

One of the main differences between the general design of the motorcycle engine and that of a small marine or an automobile engine is in construction. In the ordinary design, a one-piece crankshaft, as at *D*, is used, and this extends through the crankcase with the single flywheel *E* fastened on the outside, as in the Motor Wheel and in the Indian Light Twin. In all other motorcycle designs in this country, however, enclosed flywheels are used. In this case there is a flywheel on each side, as shown at *F*, these being housed inside the crankcase. The counter weights to balance the inertia forces of the piston are cast as part of these flywheels instead of being fastened on as is sometimes done with automobile crankshafts.

A valve assembly is shown at *G*, giving the valve, the valve seat, the valve spring, the tappet, and the cam. The valve usually has a bevel seat, as shown, but in some cases it is flat. As the cam is revolved by the gearing from the crankshaft, the high portion comes under the bottom of the tappet and raises it upward. The tappet,

in turn, raises the valve from its seat, allowing gases to enter or to be exhausted from the cylinder, as the case may be. There is often an arm, or cam follower *H*, interposed between the cam and the lower end of the tappet, but the general action is the same.

It is quite common to use an overhead valve for the inlet, and in that case the valve often works in a removable cage *H* instead of seating directly on the cylinder casting. In order to get the action of the cam carried to the valve, the tappet raises a long push rod and this, in turn, raises one end of a rocker arm, the combination of motions opening the valve.

PRINCIPLES OF ENGINE OPERATION

Classification. Motorcycle engines of all designs are of the internal-combustion engine type, which means that fuel is burned, or exploded, inside the cylinder of the engine, where the heat energy liberated is transformed into mechanical energy. An example of an external-combustion engine is the ordinary steam engine, where the burning of the fuel takes place outside of the engine itself.

There are two general types of the internal-combustion engine, known as the four-cycle and the two-cycle engines. Since these terms refer to the number of strokes of the piston for each power impulse for one particular cylinder, it would be more proper to speak of them as the four-stroke-cycle and the two-stroke-cycle, but custom has dropped the word *stroke*.

Four-Stroke-Cycle, or Four-Cycle. Taking up the four-cycle operation first, as it is the more important so far as the number of machines is concerned, we will assume that the piston has passed the upper dead center, as at *A*, Fig. 17, and that at this point the inlet valve is well open. As the piston travels downward, the explosive mixture is drawn into the cylinder, and at the lower dead center the inlet valve closes. As the piston travels back, both valves are closed *B*, and the mixture is compressed to from sixty to ninety pounds per square inch. At the time the piston reaches the top of the stroke again *C*, the spark occurs at the plug, igniting the charge. The rapid expansion, or explosion, of the gases, drives the piston down, this being known as the power stroke. The other two strokes are called the intake, or suction, and the compression strokes. At the end of the power stroke the exhaust valve opens *D*, and as the piston

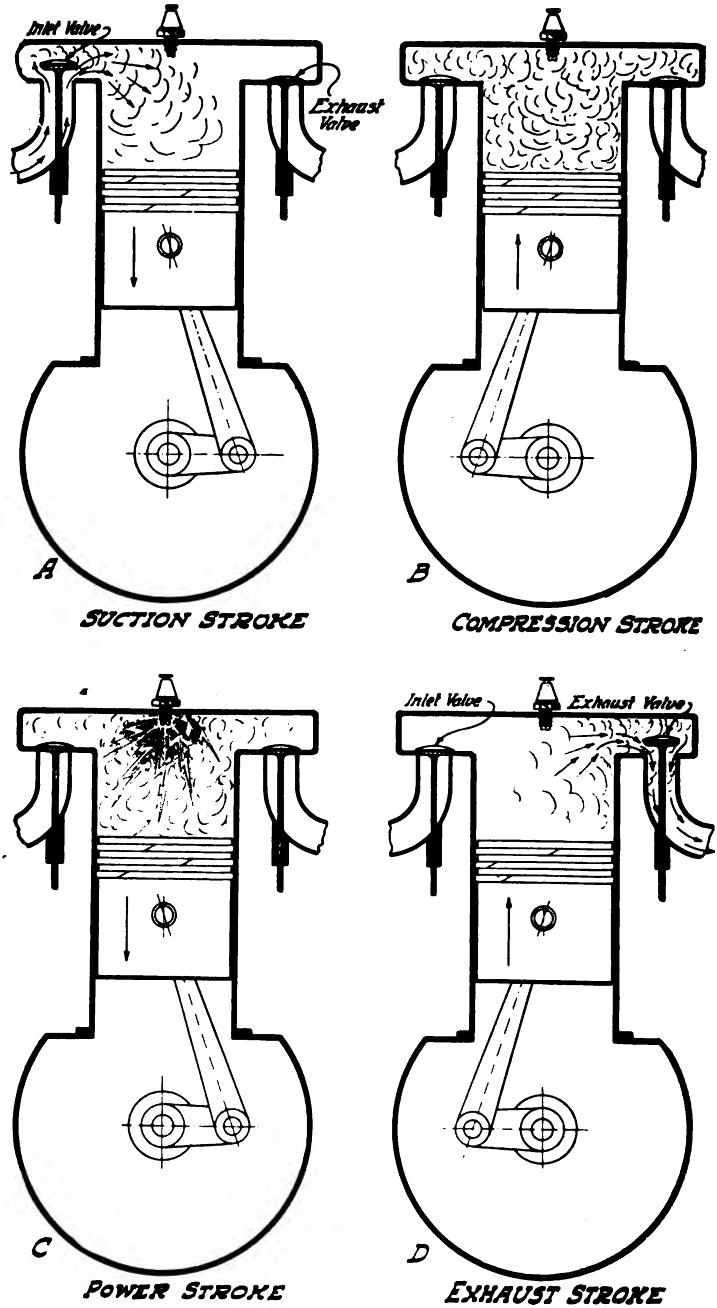


Fig. 17. Diagrams of Various Operations of Four-Cycle Engine
Courtesy of "Motor Age", Chicago

returns to the top position, the burned gases are pushed out through the exhaust valve. The cycle of events is then repeated. Thus, we have four strokes of the piston for each power impulse, and this requires two complete revolutions of the crankshaft.

Two-Stroke-Cycle, or Two-Cycle. In the two-cycle engine, the same series of operations is performed in two strokes of the piston, or one revolution of the crankshaft; and this is accomplished by the use of crankcase compression and the difference in density of hot and cold gases. Referring to Fig. 18, it will be noticed that instead of the usual poppet valves of the four-cycle engine, the two-cycle engine has

Fig. 18. Diagrams of Operation of Three-Port Two-Cycle Engine
Courtesy of "Motor Age", Chicago

openings in the side of the cylinder, which are known as ports. There are two classes of these engines, based upon the number of ports employed. The more common is the three-port engine, in which the carburetor is connected by a passage to the crankcase, the port of this passage being opened and closed by the skirt of the piston.

Starting with the piston at the lower dead center and traveling upward, there will be a partial vacuum produced in the crankcase which is air tight. When the skirt of the piston uncovers the inlet port, the vacuum will cause a rush of explosive gas into the crankcase *A*, Fig. 18. When the piston has reached the top dead center and

started down again, it will shut off this gas passage, and its further travel will compress the mixture in the crankcase to a few pounds pressure. Near the lower dead center *B*, the top of the piston will uncover the port of the by-pass from the crankcase to the chamber above. The gas in the crankcase, being under slight pressure, will rush up into the combustion chamber with considerable velocity, and, being colder than the spent gases of the preceding explosion, will drive these hot gases out through the third port, which was uncovered by the top of the piston a moment before it uncovered the by-pass.

Fig. 19. Diagrams of Operation of Two-Port Two-Cycle Engine
Courtesy of "Motor Age", Chicago

In order that the fresh gases shall not pass directly across the piston and out through the exhaust port, leaving burned gases in the top of the cylinder, the piston is provided with a deflector so as to send the cold gases up to the top of the cylinder, driving out the exhaust with as little waste of the fresh gases as possible. As the piston continues to pass upward, both the by-pass and the exhaust ports are closed again and the remainder of the stroke compresses the fresh gases. At the end of the compression stroke, that is, just after the piston passes upper dead center *C*, the spark occurs, igniting the charge and giving the power impulse to the piston. Thus we have inlet, compression, firing, and exhaust taking place in two strokes of

the piston, or, in other words, there is a power impulse for every revolution of the crankshaft.

Upon the face of things, one might think that the two-cycle engine of equal dimensions and running at the same speed as a four-cycle engine would have exactly double the power of the latter. This, however, is not so, as the method of getting the gas into and out of the cylinder is less efficient in the two-cycle than in the four-cycle design.

The two-port two-cycle engine varies from the three-port in but one particular, and that is that the passage between the crankcase and the carburetor is closed by an automatic spring-controlled valve instead of by the opening and closing of a port by the skirt of the piston. This is clearly shown in Fig. 19.

CONSTRUCTION DETAILS

Spring and Frame Construction. *Seat-Post Springs.* The springs used on a motorcycle to absorb the road shocks or to add to the comfort of the rider are usually located on the front forks, in the rear frame, or in the seat post. One of the first firms to adopt a spring-seat post was the Harley-Davidson, but the Merkel had used a spring-frame construction some time previous. The more prominent of the modern spring constructions will be illustrated and discussed.

Fig. 20. Flying Merkel Spring Seat Post

The Merkel spring-frame construction is shown in Fig. 20, a coil spring being fitted under the saddle and forming a continuation of the upper forks. In action, the lower forks are pivoted about the crankshaft of the motor below, this acting as a radius for the rear axle. The upper forks support the entire weight of the motorcycle on the coil spring.

The Harley-Davidson and the Dayton systems, which are very similar, are illustrated in Figs. 21 and 22. In these constructions, the vertical tube of the frame contains a plunger operated from a fixed center with a coil spring on either side. The saddle fastens to a radius rod at the top of this plunger, the front end of this radius rod being bolted to a clutch on the frame. The entire weight of the rider is supported through the saddle on the coil spring below, allowing a very easy-riding action.

Rear and Front Frame Springs. The Pope uses a leaf-spring front fork and a spring type of rear suspension, Fig. 23. The suspension consists of a drop-forged bracket on each side, brazed to the rear end of the frame, with a tension spring fastened to the top surface of the bracket. Double guide rods, as shown in the figure, are used, these rods carrying an axle yoke which is free to move between the jaws of the bracket, thus allowing the spring to absorb the rear vibration. Fig. 24 illustrates the Indian cradle-spring frame at the rear. This construction has the lower forks pivoted as on the Merkel.

Fig. 21. Harley-Davidson Spring Seat Post

Fig. 22. Dayton Spring Seat Post

but the weight of machine and rider is supported on the two leaf springs, as shown. The details of the front-fork leaf springs of the Indian are shown in Fig. 25.

Types of Frames. There are two types of frames ordinarily used in motorcycle construction. One is formed with a loop, as shown in Fig. 26, the motor fastening to lugs on either side of the loop. This construction makes the machine very easy to assemble, and the frame is equally strong whether the motor is in or out of the frame. The other construction is similar to this, except that the loop below is eliminated, as shown very noticeably in Fig. 9. The lugs fasten

directly to the crankcase of the motor, which thus becomes the lower member of the frame.

Motors. Motors for motorcycle use are usually of the four-cycle air-cooled variety. These motors, as previously described, are now built with one, two, and four cylinders. Water-cooling has been tried abroad on motorcycles with considerable success, but so far has not been applied in America.

Single-Cylinder Type. We have already predicted the disappearance of the large size single-cylinder engine which is still favored by some of the public-service corporations, and, at the same time, have pointed out the crop of new machines of the light-weight type which employ the one-cylinder engine, to say nothing of the popular motor-wheel type. Some of these light singles work upon the four-cycle principle, while there is also a large crop of the two-stroke variety. Fig. 27 shows a section of the Excelsior light-weight two-cycle engine, in which one of the points worth noting is the de-

Fig. 23. Pope Rear Frame Spring Arrangement

Fig. 24. Indian Rear Cradle-Spring Rim

flector built into the piston head for the purpose of causing the fresh gases to sweep clear around the dome of the cylinder before reaching the exhaust port. It may also be noted that the top piston ring is pinned,

Fig. 25. Indian Front-Leaf Spring

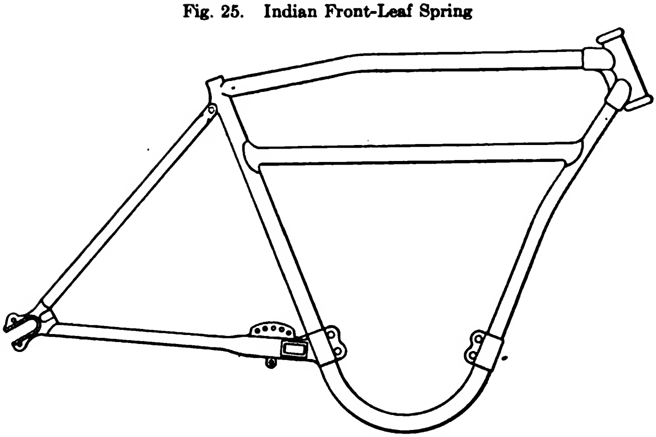


Fig. 26. Loop Frame Showing Lugs for Motor Attachment

as should be the case in all two-cycle engines in order to prevent the ends of the rings from working around and becoming snapped off at the cylinder ports. The piston is drilled full of large holes in order to

assist the lubrication and, at the same time, reduce the weight. This is another one of the engines with the outside type of flywheel and with the split-bushing-capped connecting-rod end, both similar to automobile practice. The valve at the upper left-hand portion of the combustion chamber has nothing to do with the two-cycle operation, but is merely a relief valve which releases the compression at the time of cranking.

Another single-cylinder type, Fig. 28, is the Smith Motor Wheel power plant. This type works on a four-cycle principle. The inlet valve above is of the automatic type, that is, instead of being opened mechanically, it is opened by the difference in pressure during the suction stroke. The exhaust valve is mechanically opened by the usual valve mechanism. Again, we have the outside flywheel and the split lower end to the connecting rod. In this case, the lubrication is by splash, and a large dipper will be noted upon the lower half of the connecting-rod cap. The construction of the Dayton Motor Bicycle engine is the same.

Fig. 27. Single-Cylinder Motorcycle Motor
Courtesy of Excelsior Motor Manufacturing and Supply Company, Chicago, Illinois

Two-Cylinder Type. In the two-cylinder field the V-type engines seemed to be supreme in 1915; but again the light-weight brothers have disturbed the trend of practice, and the two-cylinder four-cycle opposed engine is making as hard a fight for popular favor in the light-weight field as the single-cylinder two-cycle. In the Indian model, a cross-section of which is shown in Fig. 29, we have an example of this construction. It is the same general design which English makers have been able to run at 4000 r.p.m. in their light-weight machines. The crank throws are set at 180 degrees. In

the V-machines the cylinders stand at from 42 to 50 degrees between the center lines, depending upon the ideas of the designer. An interesting feature of the design is to be noted in the placing of the valves at an angle in the combustion chamber, making the engine very compact. The split connecting-rod bushing and the external flywheel are used.

Fig. 28. Diagram of Smith Motor-Wheel Power Plant
Courtesy of A. O. Smith Corporation, Milwaukee, Wisconsin

In Fig. 30, we come back to what we have come to think of as the highest development of American motorcycle practice, namely, the two-cylinder V-type engine. This particular figure shows the Harley-Davidson power plant, which is of the L-head cylinder construction with the inlet valve above the exhaust and operated mechanically by a push rod and rocker arm. Other engines of the

V-type have the inlet and the exhaust valves side by side in the bottom of the combustion chamber, while the third school of design places both the inlet and the exhaust valves in the top of the cylinder head, operating them through rocker arms as just described.

Instead of an external single flywheel, as we have just described in several cases, the V-cylinder engines have enclosed flywheels with the crankpin and two crankshafts fitted into them by stout tapers.

Fig. 29. Section of Indian Twin-Cylinder Opposed Engine
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

The counterbalances for the inertia forces of the piston are cast as part of the flywheels. With the single crankpin and the two rods, there are two possible constructions for the lower-end bearings. One would be with the rods placed side by side, while the other would be the forked rod as shown in Fig. 31. This is the design that has become standard practice. Although at first the amateur might think that these rods would interfere with each other, the relative motion between them is really very slight.

In the highest development of these machines, roller bearings are used at the big end of the connecting rods instead of the split bushing, which has been referred to in the light-weight engine described. Great skill is required in fitting these bearings, for if one roller is larger than the other rollers by a very small fraction of an inch, there will be a binding of the bearing upon the shaft. When they are correctly fitted, however, and properly lubricated, their life is very long, and the friction loss is held at a minimum.

Fig. 30. Side View of Harley-Davidson Twin-Cylinder Engine

Instead of the cams working directly upon the ends of tappets to raise the valves, it is usual to interpose arms, or followers, as shown in Fig. 30. Just above the cam wheel or the large gear is a small rack or portion of a gear. This is connected to the compression relief and when it is desired to relieve the compression to the motor, this part gear is rotated and, through a lever connected to it, raises both inlet valves slightly off their seats so that the compression is materially decreased.

Four-Cylinder Type. Figs. 32 and 33 illustrate the Henderson four-cylinder motor-

Fig. 31. Typical Forked Piston Rods for V-Type Twin-Cylinder Engine

cycle. This is also air-cooled and of the L-head type, with overhead inlet valves. It is designed for medium-high speed, has a three-bearing four-throw crankshaft, three-ring pistons, an enclosed flywheel, and a bevel-gear reduction. The motor is lubricated by splash from the oil in the base of the crankcase, as will be noted in Fig. 33. This motor is particularly neat, noiseless, and flexible.

European High-Speed Type. Foreigners, with their generous experimenting, have gone farther in motorcycle design than have our

Fig. 32. Rear View of Henderson Four-Cylinder Engine and Transmission
Courtesy of Henderson Motorcycle Company, Detroit, Michigan

designers in America. The progress, however, has been in the line of experimental work and individual building rather than in workmanship or in accuracy of production, the latter being the American's strong specialization. America, in spite of its heavy road conditions, is not experimenting with water-cooled motors for motorcycles, though England uses them to a limited extent. One of the most prominent motorcycle builders in England departs from standard practice in adopting both water-cooled and two-cycle principles.

Consistent performance as a result of these innovations, coupled with good workmanship, has given this machine great prominence.

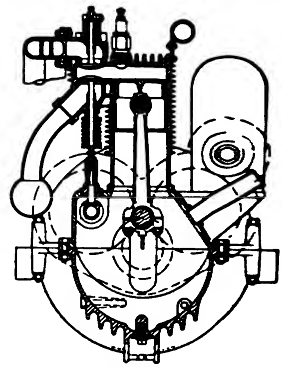


Fig. 33. Side and End Sections of Henderson Four-Cylinder Motor

Europe's greatest advantage, however, in motorcycle construction has been exemplified by the development of the high-speed motorcycle motor. This is ordinarily of the horizontal-opposed type, the most prominent high-speed low-weight construction being the Douglas, a British machine. This motor is able to maintain this high speed through a crankshaft balance which is practically perfect, allowing it to run at the abnormally high speed of 4000 r.p.m. for long periods without fatigue of material, and hence with great efficiency. The motor is of the L-head type, with air-cooled cylinders and an outside flywheel. The cylinders being placed opposite each other, the counterbalanced cranks are set 180 degrees apart. The entire motorcycle is said to weigh under 200 pounds and attains speeds well above a mile a minute.

Fig. 34. Excelsior Lubricating System

Water cooling is another English experiment, which has proven successful. It has not been generally adopted in Europe, however, and air cooling has been perfectly satisfactory in this country.

Lubrication. *Path of Oil.* A lubricating system, as used on the Excelsior motorcycle motor, is shown in Fig. 34, and gives the particularly neat method by which motors of this type are oiled. In this case, the oil is first fed to the main bearing on the cam-case side, as shown by the arrow. This oil is fed by pressure from a pump and, after covering this bearing, is forced out at the end and flows through the drill hole shown, which brings it out above by centrifugal force to the connecting-rod bearing. This bearing throws the excess oil out, splashing it in all directions and up through the slot through which the connecting rod runs. From here it runs out on either side and gathers in a groove at the bottom edge of the cylinder. The bottom of the piston drops into this trough of oil every time it comes down, thus carrying the even film with it up the walls of the cylinder. The excess oil flows down the side of the crankcase and feeds the right-hand bearing. Excess from here is caught on the outer end of the shaft and returned to the crankcase, where it is splashed up again into the motor for further use.

Fig. 35. Excelsior Oil Pump

In a V-type twin-cylinder motor where the oil trough at the bottom of the cylinder cannot catch an even amount on account of the cylinder angularity, the oil is generally allowed to drain back at once on the rear cylinder, and, instead of going to a main bearing first, it is fed to the forward cylinder.

Fig. 36. Indian Roller-Cam Oil Pump

Oil Pumps. Fig. 35 shows a type of oil pump which is used to feed the oil to the motor. In this construction a small worm drive

from the cam case or the magneto gear case turns a small crank which operates a vertical plunger. This plunger cylinder is so arranged that on the top of the stroke oil may flow into the cylinder space, a ball check valve holding the oil from being sucked into the cylinder. On the down stroke, the oil inlet is covered by the piston, and the ball check valve opens to allow the plunger to force the oil in the cylinder out of the motor.

Fig. 36 illustrates a special type of pump, in which the plunger P is operated by a peculiar-shaped roller cam H.

Fig. 37. Excelsior Starter with Compressed Air Control

Fig. 38. Indian Kick Starter
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

The shaft of this roller cam contains the elements of a rotary valve, with openings at A and D, so that the oil is fed positively through a sight feed G on its way to the motor. There are no ball check valves in this construction, and a screw J enables one to adjust the amount of

oil delivered to the motor within very narrow limits. The intake oil pipe is shown at S. The oil is fed to the motor through the opening G. Since oiling is so important a part of the high-speed motor operation, the development of this device has made a change in the reliability of the modern motorcycle.

The quality of the oil used is of great importance in the life of a motorcycle. Each maker recommends oils suited to his machine, and it is well to follow these suggestions.

Starting. It is hardly probable that the complication of electric starting will be adopted widely for motorcycle use, as it is generally more trouble to operate a power starter and keep it in repair than to use the simple form of kick starter which has become so popular and which now is fitted to almost all American machines.

Figs. 37 and 38 show forms of starters in use on the Excelsior and Indian motorcycles, respectively. The main shaft on one side or the other is fitted with a small gear pinion which is fastened to the shaft on a ratchet or over-running clutch. Off to one side is pivoted a gear quadrant fastened to a pedal, which is often of the folding type. Pushing down on this pedal with the foot meshes the pinion with the quadrant, and a quick thrust or kick of a quarter-turn will then turn the motor over several times at fair speed. When the motor starts, the small pinion is released, and a strong pull brings the quadrant back to its former position, out of mesh with its pinion. The pedal is generally fastened in this upward position by means of a clip so that it cannot rattle.

Fig. 39. Typical Expanding-Band Brake
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

Brakes. A number of types of brake construction are used on motorcycles, but they are mostly of the expanding- or contracting-band variety. Fig. 39 shows the construction of an expanding-band brake. The band is of springy material and covered with a brake-lining material. The shoe, or ring, fits inside the brake drum which is keyed to the rear-wheel hub. Operation of the lever pushes

the ends of the band apart so that it expands forcibly against the interior of the drum.

A similar band may be fitted outside the drum, but in this case the fabric will be on the inside of the band, and the lever will pull the band tight on the outside of the drum. This is known as the contracting-band brake. Fig. 40 shows the brake used on the Excelsior motorcycle combining both types, the expanding and contracting

Fig. 40. Typical Double-Acting Band Brake
Courtesy of Excelsior Motor Manufacturing and Supply Company, Chicago, Illinois

bands being shown in section with their linings in place. The operation is by two levers, shown in the lower part of the illustration.

Fig. 41 illustrates the pedals fitted to the Henderson motorcycle, which operate the brakes of this complete little machine.

Drive. *Belt Drive.* The early motorcycles employed belt drives of either the V- or the flat-faced types. As the power output increased, the belt slippage became excessive and the chain drive began to predominate. In the new light-weight machines, however, the belt drive has reappeared, especially in the V-type of construction,

which consists of a continuous two- or three-ply belt of leather with blocks of leather riveted to it, Fig. 42. The blocks are about 1 inch thick, and the sides are beveled off at the same angle as the V-pulleys.

Fig. 41. Henderson Foot Rest and Brake Pedals

Fig. 42. Peerless V-Belt for Motorcycle Drive
Courtesy of Peerless V-Belt Company, Cedar Rapids, Iowa

Shaft Drive. The Pierce Company of Buffalo at one time built a shaft-driven four-cylinder motorcycle, but discontinued it after a few seasons. The shaft drive is again announced on the Militaire, a four-cylinder machine, already shown in Fig. 14.

Fig. 43. Indian Multiple-Disc Clutch and Three-Speed Gear Set

Chains. For heavy powers the roller chain seems to have proved itself the most efficient. This construction is the outgrowth of bicycle practice, and we now usually find two chains, one from the engine to the gearset and the other from the gearset back to the rear hub. The

chain is made up of a series of rollers turning on hardened pins which stand between the side bars. If kept in proper condition, the friction loss is very small.

Clutches. Several kinds of clutches are used on motorcycles, the one most used being of the multiple dry-disc type, as shown at the left end of Fig. 43. This consists of a number of thin metallic discs faced with fabric brake-lining material and keyed alternately to the center shaft and the containing drum. When springs are allowed to thrust these plates tightly together, the amount of friction generated makes a reliable drive between the drum and the central shaft. Suitable mechanism is arranged so that, when it is desired to disengage the clutch, a lever or pedal can release this spring pressure and allow the discs to run free without friction between them.

Fig. 44. Sectional View of Reading-Standard Cone Clutch

Fig. 45. Indian Neutral Countershaft
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

Metal-to-metal clutches consist of a set of metal discs brought into or out of contact by means of a lever. These are generally run

in oil to prevent their heating. When the spring pressure is applied, it takes a number of revolutions to drive out the oil from between the plates and thus prevent a grabbing clutch.

The Reading-Standard motorcycle, instead of employing a countershaft back of the motor, fits an internal-gear countershaft to the side of the crankcase and drives from this to the main drive sprocket by means of an ordinary automobile-type cone clutch. This clutch is shown in Fig. 44. A cone on this clutch is faced with leather and operates exactly like an automobile clutch.

Gearsets, or Change-Speed Mechanisms. Modern motorcycles are almost invariably fitted with change-speed gears, which might be classed as one-, two-, and three-speed types.

One-Speed. The one-speed gear — if it can be so called — is merely a dog-clutch arrangement, Fig. 45, used to disconnect the motor from the rear wheels when the clutch is in engagement. The central part is a ring which can be moved from right to left in order to fit the notches in its face into those on an adjacent ring connected to the driving sprocket. The sliding of this member is accomplished by means of the small lever.

Fig. 46. Dayton Multiple-Disc Clutch and Sliding-Gear, Two-Speed Transmission

Two-Speed Planetary. Where but two speeds forward are desired, the planetary, or epicyclic, gearset has proven popular. This type, which is sometimes called the sun and planet gear, is made up of a nest of small gears which usually mesh with an internal gear at the same time that they are revolving about a common center gear. The small gears not only revolve in space, but also revolve upon their own axes. By holding the internal gear in place, a desired reduction can be obtained. Such gears were employed upon the Harley-Davidson and the Henderson; but, as mentioned before, the

trend is toward the three-speed sliding-gear transmission, and none of the late catalogues of the well-known makers list the planetary gear.

Two-Speed Gear. Fig. 46 shows a Dayton sliding ring two-speed transmission fitted with a multiple-disc clutch, shown in section. This clutch is operated by a lever or pedal and, when in engagement, enables the sprocket at the left to drive through the gear mechanism to the middle, or main drive sprocket. If the small cam ring, shown in the center of the gearset, is moved to the left by a lever, the dogs engage a shaft from the left sprocket direct to the main sprocket, so that one is driving on high gear. On releasing the clutch, the cam

Fig. 47. Harley-Davidson Three-Speed Transmission

ring in the center of the gearset can be shifted to the right to mesh with the smaller gear on that side, which is driven by the sprocket at the left. This gear now drives through the two lower back gears, back through the upper left-hand gear to the main sprocket, which now, instead of traveling with the left one, travels at about half its speed. This is low-gear position. This type of gearset is used on a number of prominent motorcycles, the differences being mainly in details.

Three-Speed Gear. Fig. 47 shows a three-speed gear fitted to the Harley-Davidson, operating on the same principle as the two-speed gears just mentioned. At the extreme left is shown the clutch and the large and small sprockets. The lower shaft to the gearset is

the main shaft, and the two gears at the right on this lower shaft slide on keys on the shaft. The shaft is driven by a big sprocket, while the smaller sprocket is fastened to the left-hand gear. If the two sliding gears are shifted to the left, a dog engages them with the left-hand gear, these dogs being clearly seen in the cut. If the gears move to the position shown in the cut, the machine is on second speed, driving through the four gears which are in mesh. If the two gears are shifted farther to the right, the right-hand one of the two lower gears comes in mesh with the right-hand big gear, and the machine is on its lowest gear ratio. The method of mounting this gearset on the Harley-Davidson is shown in Fig. 48.

Fig. 48. Method of Mounting Transmission in Harley-Davidson Frame

A smaller three-speed gearset used on the Indian motorcycle is shown in Fig. 43 in connection with the disc clutch attached. In this case a single sliding gear on the princpial shaft makes all the connections and gives a progressive gearset of extreme simplicity. A gearset is a necessity on motorcycles intended for passenger use.

Electrical Equipment. *Development from Battery Current.* In the earlier days of the motorcycle, the electrical current for ignition was furnished by dry cells and stepped-up to the required voltage by an induction coil. The next development was the almost universal equipment with high-tension magnetos, which generated the spark

Fig. 49. Remy Generator as Used on Harley-Davidson Motorcycle

mechanically and directly furnished high-tension current. With the coming of electric lighting and starting equipment on all automobiles, the motorcycle enthusiast saw the advantage of the electric head and tail lights, to say nothing of a warning signal, and was not slow to demand this upon his own type of machine. The very nature of dry cells works against their continual use for supplying headlight current, and the storage battery has therefore been the only solution of the problem. A storage battery, however, to be carried upon the motorcycle must be rather small in size and thereby limited in capacity.

Fig. 50. Splitdorf Magneto Generator as Used on the Indian Motorcycle

In the history of automobile lighting, the owner soon demanded that a generator be driven by the engine for the purpose of keeping the storage battery in a charged condition, instead of having to take it some place for charging from an external source. The same thing followed in the motorcycle field; and we have seen developed a series of generators, Fig. 49, driven mechanically by the engine, which are capable of keeping the battery floating on the line or of sometimes taking care of the lights.

Fig. 51. Parts of Splitdorf Mag-Generator
Courtesy of Splitdorf Electric Company, Newark, New Jersey

Magneto Generators. These generating machines — the Splitdorf type shown in Fig. 50 is used on the Indian—are a unique conception and apparently have not been influenced by automobile practice, for the instruments usually combine a high-tension magneto and a low-tension generator. This combination makes a single-unit machine mechanically, but a double-unit machine electrically, there being two separate armatures, as shown in Fig. 51, the same field winding exciting both fields. In a way, it is wrong to speak of this as partly a magneto, because the term magneto implies the use of permanent magnets for the production of the magnetic field. The armature, however, is of the regular magneto type and delivers a high-tension current to the spark plug. The generator armature is wound so as to deliver about three amperes of current at thirty miles per hour, charging a 6-volt battery. The above description covers, in general, the Splitdorf system.

In automobile practice it is very common, at present, to use the battery or generator current for the ignition; and, in order to do this, a transformer coil is used to step-up the 6-volt current to the extremely high voltage required to jump the spark gaps. This coil is very often mounted right on the generator. The same practice is followed on some of the motorcycle systems, one being the Midco system used upon the Excelsior, Fig. 52. The ignition current is stepped-up by two small coils which are mounted in a protecting case directly above the generator, as shown in Fig. 53. In a system of this kind there must be both a circuit-breaker and a distributor; these two devices are mounted upon the end of the main drive shaft of the machine as shown.

Fig. 52. Midco Magneto-Generator as Used on Excelsior Motorcycle
Courtesy of The Teagle Company, Cleveland, Ohio

Automatic Switches. In all electrical systems charging the storage battery, it is necessary to have an automatic switch between the generator and the battery and also some kind of device for regulating the output of the generator so that it will not rise to too high a value

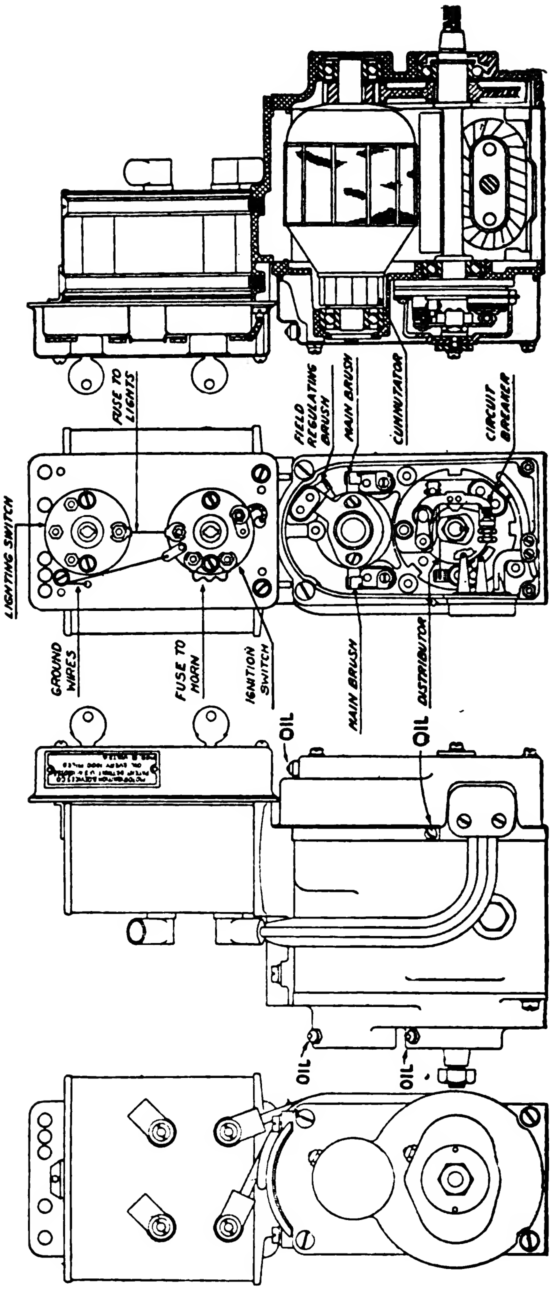


Fig. 53. Side, End, and Sectional Views of Midco Magneto-Generator
Courtesy of The Teagle Company, Cleveland, Ohio

at very high speeds of the engine. The first instrument is variously known as a cut-in, cut-out, relay, etc., and is merely a device to keep the circuit open as long as the battery voltage is higher than the voltage being delivered by the generator. Of course, when the engine is at rest, the generator voltage is zero, and it is not until a road speed of some 8 to 12 miles per hour is attained that the voltage rises above the 6 or 6½ volts of the storage battery. If the circuit was not kept open during this period of still engine or of slow running, the battery would discharge itself through the generator. These relay cut-in switches are usually of the electromagnetic type; and the pull of the magnet when the generator is giving out seven volts closes the circuit, and the generator begins to charge the storage battery. If the lights are on, the generator may take care of the light load and, at high speed, charge the battery besides. As the engine slows down, our conditions for wasting the storage-battery current through the generator appear again, and the automatic switch opens the circuit.

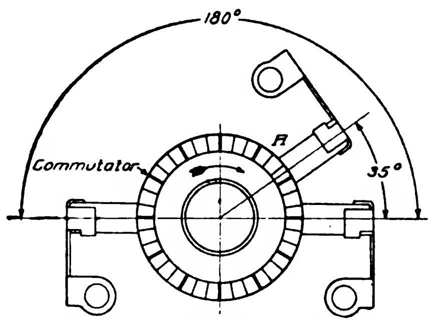


Fig. 54. Midco Third-Brush Regulation

Regulation. Roughly speaking, the voltage and therefore the current, other things remaining equal, of a generator increases with the speed of the machine. If the generating device is designed to keep the battery in a charged condition at reasonable driving speeds, one can imagine the high charging rate that would result if there were no regulation of the output, and the driver "let her out" for several miles over a fine stretch of country concrete. Such a charging rate would probably burn out the winding of the generator itself and also cause serious damage to the battery, owing to overheating and a resulting buckling and falling to pieces of the plates of the battery. One method of regulation is to take advantage of the distortion of the field and attach one end of the field windings to a third brush, as at A, Fig. 54. This is known as the third-brush regulation and as the speed increases, the strength of the field automatically decreases, thus counteracting the effect that speed ordinarily has upon the current output. In other cases

the regulation is accomplished through the throwing in of resistance into the field circuit, which is done automatically by means of an

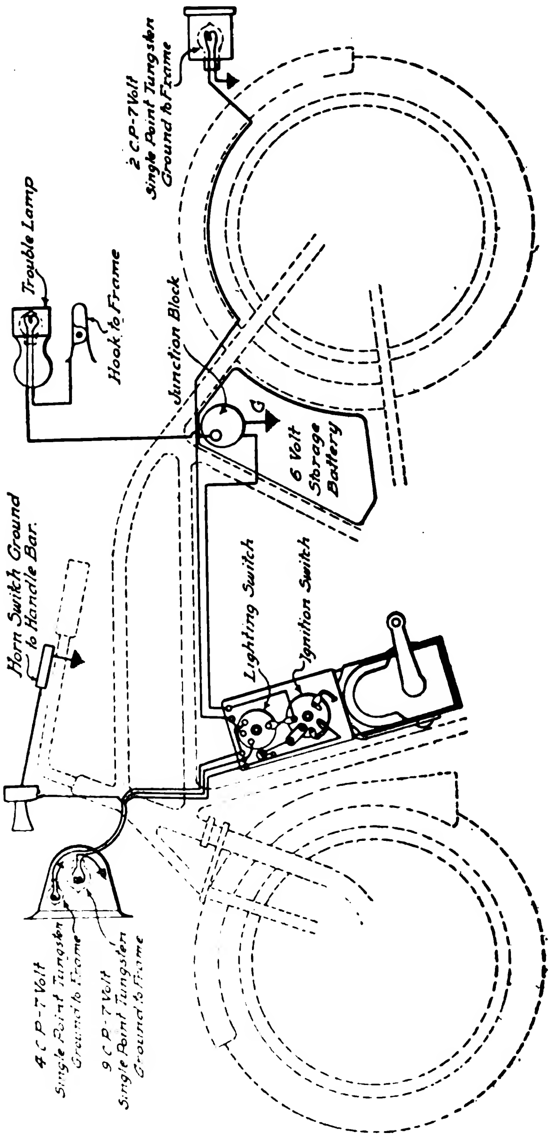


Fig. 55. Wiring Diagram of Midco System on Excelsior Motorcycle
Courtesy of Excelsior Motor Manufacturing and Supply Company, Chicago, Illinois

electromagnetic device very similar to and often combined with the relay switch.

One- and Two-Wire Systems. There is the same variation in practice in the motorcycle field as on the automobile in regard to the one- and two-wire systems. The one-wire system is also known as the single- or grounded-return system, and the two-wire as the ungrounded-circuit system. In the grounded-return system but one wire is led to each lamp, and the current passes back through the fixture and through the metal parts of the motorcycle to the grounded side of the storage battery. In the two-wire system a wire runs both to and from each bulb, and there are two contact points in the base of the lamp bulb. Thus, in purchasing lamp bulbs, one must examine the old light to see whether it is of the single- or the double-contact type.

Fig. 56. Splitdorf Ammeter

It is not advisable to add much more electrical equipment than comes with the machine, such as cigar lighters, hand warmers, and what not, for these put a load upon the storage battery not calculated in the design, which will cause not only unsatisfactory holding of the charge but also a possible heating and buckling of the plates, owing to excessive discharge. Fig. 55 shows the wiring diagram of the Midco system on the Excelsior amd indicates a double headlight of nine candle power and four candle power and a tail light of two candle power. It will be noted that the bulbs are marked 7-volt, while the Midco is a 6-volt system. Seven-volt lamps are used because they give satisfactory light and still have a very long life. Six or six and one-half volt lamps will work perfectly well, but will burn somewhat more brightly and will not last as long.

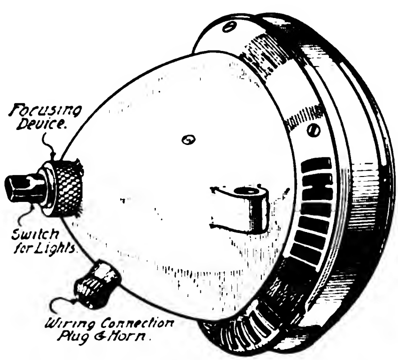


Fig. 57. Combination Headlight and Horn

Ammeter. In case one has an electric generator and a storage battery upon his machine but no ammeter, it is well to provide such an instrument, shown in Fig. 56, as it gives a close check on the condi-

tion of the system at all times. The most valuable type is that with a zero in the center and a charge scale reading one way and a discharge scale reading the other. These instruments are usually wired into the system, so that they do not show the actual generator output, but rather the output and input of the storage battery. The rider, however, soon learns to know whether or not the generator is more than able to take care of the lamp load at any certain speed, that is, whether it also can charge the battery. One of the valuable features of the instrument is that it will show a short-circuit of any account.

Fuses. Another device in the electrical system is the fuse. This is a piece of wire which will melt when a current of greater value than is normal for the system is passed through it. The wire is carried in a small cartridge which slips between the clips on the fuse block.

There is hardly another place where space is at a greater premium than upon the modern motorcycle; and to assist in its conservation a combined headlight and horn, shown in Fig. 57, has been brought out.

Storage Batteries. The storage battery, Fig. 58, which is such an essential part of the new complete electric-lighting and ignition equipment, is made up of a series of composition lead plates and a solution of sulphuric acid known as the electrolyte. The plates of two kinds, positive and negative, are assembled alternately positive and negative to form a cell. Each cell has a potential of a little over 2 volts, and there are therefore 3 cells connected in series to form a 6-volt storage battery. The capacity of the battery, that is, its ampere-discharge rate, is dependent upon the number and the size of the plates. Because of the very limited space on the motorcycle, it can be understood that only a battery of small capacity can be used. It is, therefore, even more necessary than in automobile work to make sure that the generator is charging at its proper rate.

Fig. 58. Typical Motorcycle Storage Battery
Courtesy of Willard Storage Battery Company, Cleveland, Ohio

When the battery is fully charged, and everything is in good condition, the density of the electrolyte should be from 1250 to 1300, as read by the hydrometer syringe. As the battery discharges, the density decreases and should not be allowed to drop below 1150. The charging and discharging of the battery results in the generation of a certain amount of heat, which causes the water in the electrolyte to evaporate through the vent plugs. This must be replaced at least once a week with distilled water which has not come in contact with a metal vessel. Ordinary drinking water or distilled water which has been kept in a metal vessel contains enough minerals to cause local action within the battery, which greatly shortens its life. The Society of Automobile Engineers has formulated a set of rules for the proper care of a storage battery. These rules will be found in the article on Electric Automobiles, or can be provided by the battery manufacturers. They should be carefully read by every storage-battery owner.

Spark Plugs. While on the subject of electrical equipment, it may not be out of place to mention the variety of spark-plug standards. The majority of motorcycles use what is commonly known as the metric plug, which means that the fine threads on this plug are cut according to the metric system. The ½-inch pipe-thread plug, which is cut upon the same taper as the usual pipe standards, also is used in motorcycle engines. There is still another very common plug standard, which does not seem to have been taken up by the motorcycle makers, but which might be purchased easily by mistake. This is the S.A.E. ⅞-inch plug with eighteen threads per inch. In the early days of the automobile industry, this same plug, which is distinguished by a shoulder and a copper gasket, was known as the ALAM plug. Every motorcycle owner should know with what type of plug his machine is equipped, so that he will not be buying and carrying about with him, for an emergency, plugs which would be of no service.

Fig. 59. Simple Passenger Attachment for Motorcycles

SPECIAL BODIES AND ATTACHMENTS

Passenger Attachments. The motorcycle has become so popular a vehicle that owners wish to take their friends with them, hence has come about the popularity of passenger attachments. Fig. 59

Fig. 60. Harley-Davidson Side Car
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

shows the simplest type of passenger attachment for motorcycles. This attachment consists of an extra seat that fastens at the back of

Fig. 61. Harley-Davidson Commercial Van
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

the driver's seat, which makes a tandem vehicle of the machine. Many thousands of these are in use in America. While at first they were viewed with a certain degree of contempt by the automobilist,

they have become accepted as a proper means of conveyance. Many motorcycle owners who are not possessors of this attachment fit a heavy cushion to the luggage carrier over the rear wheel and mount a passenger on this.

Seeking for more dignity in a passenger attachment, motorcycle riders have adopted sidecars, shown in Fig. 60, as a solution. Separate upholstered body constructions are fitted with an extra wheel, all of

Fig. 62. Rear View of Flxible Side Car Showing Truss Frame and Spring Arrangement
Courtesy of Flxible Side Car Company, Loudonville, Ohio

which attaches to the side of an ordinary motorcycle so that the passenger may be carried in a comfortable conveyance alongside the driver.

The Harley-Davidson Company also manufactures what is called a commercial van, Fig. 61. This, it will be noticed, is built on the same chassis as the regulation sidecar, Fig. 60, a box taking the place of the passenger body. Sidecars are becoming more popular every year, as the length of good roads is increasing. Their chief

disadvantage is the side strain caused by the pull of the third wheel. Improvements have been made in sidecar construction, as well as in all other motorcycle developments, and the design known as the Flxible Sidecar, shown in Fig. 62, is intended to relieve much of the side strain on the machine when rounding corners. Not only do we have sidecars and rear seats for carrying passengers, but there is manufactured a series of rear cars, which goes so far as to include a limousine, Fig. 63.

The framework for these sidecars, rear cars, etc., furnishes an opportunity for all kinds of commercial applications, and besides the

Fig. 63. Unique Motorcycle Limousine
Courtesy of Cygnet Rear Car Company, Buffalo, New York

light delivery in all forms, including the motor wheel, the motorcycle chassis has been fitted out to carry machine guns, fire-fighting equipment, life-saving apparatus, etc.

Cripples have also taken advantage of the sidecar and have had levers and rods rearranged, until it is possible for them to ride in the car and operate the whole machine therefrom.

Novelties in Motorcycle Equipment. The motorcycle manufacturers have lately made other substantial additions to their

equipment. One of these is the three-wheeled motorcycle in which seats for two or three passengers are built around the rear axle; but, in

Fig. 64. Dayton Tri-Car Chemical—An Efficient Chemical Fire Engine for Small Fires
Courtesy of Davis Sewing Machine Company, Dayton, Ohio

the face of the failure of the cyclecar and the light-car types and the consequent reduction of the price of the smaller standard-tread cars

to considerably less than $500, this new form of tricycle seems hardly justified. Improvements in the styles of package vans also have been made. Still another novelty has been put out by the Davis Sewing Machine Company, which consists of a three-wheel chassis carrying a fully equipped chemical engine, Fig. 64. Such a device has so much

Fig. 65. Thor Front Stand, Showing Usefulness When Removing Front Wheel
Courtesy of Aurora Automatic Machinery Company, Chicago, Illinois

more speed than the horse-drawn chemical engine and is so much lighter than the combination chemical and steam fire engine that its adoption should be a matter of time only. So many fires are put out by the aid of a few hand grenades or by the "chemical" that a light engine of this type, capable of 30 to 45 miles per hour, would be a

distinct advantage. These are useful in suburban districts where neither the water supply nor the fire-fighting equipment are always adequate.

This tri-car is well built, the chemical equipment being carried on a steel frame running from the front axle to the crankcase. The load is carefully balanced, and seats are provided for two men.

Front Stand. Each year brings out some small device which adds to the comfort of the motorcycle rider. Among the latest of these small improvements is the front stand, by which the motorcycle can be made to stand alone with the front wheel removed, as shown in Fig. 65. This will be particularly appreciated when the rider is in the country and has to work upon either the front tire or the front wheel itself, as that is the time when the soap box support is never available.

OPERATION AND REPAIR OF MOTORCYCLES

OPERATION SUGGESTIONS

The Motor. When the motor is in good working order, it requires practically no attention other than to supply it with fuel and keep it properly lubricated. When any serious trouble occurs, a safe plan is to take the machine to an expert and have it properly repaired. This will usually prove the cheapest way in the end. Some of the more common sources of trouble may, however, be located by the use of a little common sense and judgment. It is of fundamental importance that the motor should be securely attached to its base, as otherwise it may be twisted around by the belt or chain, and thus thrown out of alignment. It is, therefore, a good plan to go over the motor and its connections from time to time, tightening up all loose nuts.

A very common form of trouble is indicated by a knock, or pound, which will ordinarily be found to be due either to lost motion or to premature ignition. The pounding due to lost motion indicates too much play between parts which have relative motion and would most commonly be caused by looseness of connecting-rod or crankshaft bearings. Premature ignition, on the other hand, causes pounding of a sharper and more metallic sound and may be due either to overheating or to the fact that the spark is advanced too far. In some cases it also may be caused by carbon deposits in the cylinder, which become incandescent and in this manner cause premature ignition of the gas, A good way to locate a knock is by the sense of

sound, which may be assisted by putting one end of a piece of metal, such as a heavy wire, against different parts of the motor and holding the other end between the teeth. The source of the trouble will then be indicated by excessive vibration as the wire approaches it.

The forming of carbon in the cylinder is objectionable, since it causes overheating and loss of power as well as premature ignition. This can be avoided by occasionally injecting into the cylinders a small quantity of kerosene while the motor is warm, turning the engine over a few times, and leaving it thus over night. In the morning the kerosene should be forced out by turning the motor over; the foul oil should be drained from the crankcase and replaced with fresh oil.

The leakage of gases from the cylinder, escaping past the pistons, because of wear either in the cylinder or in the piston rings, is likely to cause overheating of the upper part of the crankcase. When it is found difficult to turn the engine over, the cause is probably the overheating and consequent binding of the piston.

Valves. In order to obtain the best results from the motor, it is important that the valves should be properly seated, and that the springs should be neither too stiff nor too weak. It is somewhat commonly supposed that grinding the valves will prove a cure for almost any of the ills to which the gasoline motor is heir. This is a mistake, and valve grinding should not be resorted to unless it is necessary. The grinding of valves is a comparatively simple process, but one that should not be carried to excess as it lowers the valve on its seat; this produces the same effect as does the lengthening of the valve stem, namely, prevents the valve from seating properly, thereby causing a difficulty greater than that which the grinding was expected to relieve. In order to grind a valve, a paste should be made from emery and oil. This should be put both on the seat and on the edge of the valve itself. Then the valve should be placed in position and turned slowly in its seat by means of a screwdriver, a steady pressure being maintained meanwhile; the turning should, for the most part, be in one direction but an occasional part-turn backward should be taken. During the process, care should be exercised to see that the pressure is in a perfectly vertical direction, as otherwise an uneven grinding will result. In order to tell when this process has been continued long enough and the valve is properly ground, the surface of the valve seat and also of the valve may be coated with smoke from a

candle; the valve should then be placed carefully in its seat, turned completely around once, and examined. If the grinding has been properly done, a complete bright ring will be seen all the way around. Breaks in this ring indicate that the grinding should be continued.

Carburetor. The proper action of the carburetor is of vital importance to the smooth operation of the motor, and, on this account, when anything goes wrong, it is very common for a beginner to decide at once that the trouble is in the carburetor and begin to tinker with it. As a matter of fact, however, it would be wise for the novice not to attempt any adjustment of the carburetor until he has made a careful study of the type he is using.

Ordinarily, the motor should start without priming the carburetor, unless it has been standing a long time, or unless the weather is cold. In case it does not start readily, priming may be resorted to, although it should be remembered that over-priming does more harm than good, since the motor then becomes supplied with too rich a mixture, which is as hard to fire as one which is not rich enough. If the gasoline refuses to flow altogether even after priming, the trouble can sometimes be relieved by blowing into the opening of the gasoline tank. Ordinarily, about the only attention the carburetor requires is an occasional cleaning, the frequency of which depends very largely upon the quality of the fuel used and the care with which it is strained. In case the spray nozzle becomes so seriously choked that blowing into the tank will not relieve it, the difficulty can usually be overcome by holding the finger on the priming pin until the carburetor floods, simultaneously racing the motor.

The adjustment of the carburetor can be determined by observing the exhaust. If the mixture is too rich, black smoke and red flame will appear. If it is not rich enough, it will be indicated by a yellow flame, while normal conditions are indicated by a blue flame. An important point to bear in mind is that the proper mixture varies with atmospheric conditions and that a richer mixture is required in cold or damp weather than when it is hot or dry.

Ignition. In connection with the ignition system, it is necessary to be sure that all connections are clean and firmly made and that the insulation is sound throughout. In case of battery ignition it is, of course, necessary to see that the batteries are in good condition. In order to get the best results from the batteries, it is well to

have an ammeter with which to test them. New batteries should test from 15 to 18 amperes and about 1.5 volts. When a battery has run down to 4 or 5 amperes, it can no longer be depended upon and should be thrown out. Each cell should be tested separately, and it is never well to connect an old cell with new ones, as the old cell tends to reduce the life of the new ones. The terminals of a battery should never be short-circuited by testing directly across them with a wire or screwdriver, as a battery can be completely exhausted in this way in a short time. It is well to go over all joints and connections periodically, making a careful examination to see that all binding posts and set screws are tight and that all points of electrical contact are bright and clean. The insulation also should be examined from time to time, looking not only for spots where the insulation has been worn away by chafing, but also for any places where it has become saturated with oil. Inspection of this sort is particularly important in the secondary winding, because the insulation in this winding must be much more perfect, on account of the high voltage employed, than in the low-tension primary wiring. In regard to the contact-breaker, it is important to see that it is properly adjusted and that the platinum tip is clean and bright.

A common cause of trouble in the ignition system is due to soot on the points of the spark plug. The spark plug should accordingly be removed occasionally and the points cleaned.

The magneto is very seldom the cause of trouble and, under ordinary conditions, should not be tampered with by an inexperienced person. One common source of trouble with the magneto, which can be easily relieved, is the binding of the carbon brush in its holder, thereby preventing proper contact between the brush and the commutator. The same thing will, of course, result if the spring which holds the brush against the commutator becomes weak or is broken.

Lubrication. The matter of lubrication has already been mentioned, but it is so vital to the satisfactory operation and to the life of a motorcycle that it will bear repetition. The oiling should not be a perfunctory operation to be taken care of at random, but should be done methodically at intervals depending upon the grade of oil used. Of course, it is possible to go to extremes and oil too frequently, but too much oil is more preferable than too little.

Only the best grade of oils should be used, as the difference in cost is only slight, and a poor oil is sure to cause trouble. The manufacturers are always glad to give advice as to the kind and grade of oil best suited to their make of motor, and one would do well to be guided by such advice, since no one knows a machine so well as the maker, and it is also to his interest that the machine give a good account of itself.

Tires. The principal point to be borne in mind in connection with the tires is that they should be kept pumped up hard, as riding on soft tires is likely to injure both the casing and the inner tube, as well as requiring more power to drive the machine. A tire pump should always be carried when on the road, and the condition of the tires should be examined frequently for any indication of softness.

A spare inner tube, sprinkled with tire powder, carefully folded, and enclosed in a separate package, should be carried along for replacement in case of a puncture or a blow-out. In addition, a tire-repair outfit for making quick repairs on the road should always form part of the rider's equipment.

In replacing tires with metal tire tools, care should be taken not to chip the enamel off the rim, as this will cause it to rust, and the rust will, in turn, injure the tires. On this account, it is well to paint the rims occasionally as a guard against rust. Grease and oil are very injurious to rubber and should never be allowed to remain on the tires, but should be washed off at once with gasoline.

Control. The speed and the amount of power developed by a motorcycle depend upon two factors: the quantity of gas supplied to the motor; and the time at which the spark occurs with relation to the position of the piston in its travel back and forth in the cylinder.

The devices for controlling these two factors or for regulating the throttle and the spark should be conveniently located so that they can be manipulated instantly, while at the same time keeping the hands in position upon the handlebars.

Nearly all the earlier machines were equipped with the twist-grip type of control in which twisting one grip varied the position of the throttle and the other the position of the spark. This type of control has the disadvantage that in heavy going where a firm hold on the handlebars is necessary the rider is in danger of twisting one or both of the grips unintentionally, thereby varying the position of

the throttle or spark at the wrong time. This objection is overcome to a large extent by having the twist grip located in front of secondary grips which are rigidly attached to the handlebars.

Handlebar, or lever, control is rapidly coming into favor. This form of control consists of levers placed in front of the grips with rod and knuckle joints or with wire cable leading therefrom to the carburetor and to the spark mechanism. Cable seems to be the more satisfactory, for with its use there is no lost motion as is the case with the rod and knuckle-joint system. An advantage of the lever type of control is that the exact position of the levers can be seen at a glance.

Whatever the type of control, the rider should so accustom himself to its manipulation that he can, in case of emergency, throw off the power and apply the brakes instantly. In fact, these operations should be so familiar as to become automatic.

General Instructions. Before starting out, the rider should be sure that he has an ample supply of gasoline and oil in the tanks, never using anything but strained gasoline. The machine should be well oiled and the tires examined to see if they have sufficient air. All bolts, nuts, and screws should be gone over, and tightened if necessary. The wiring should be examined for loose connections or breaks in the insulation, and the batteries should be tested with an ammeter. Any excessive slack in belt or chain should be taken up. If these matters are attended to systematically before starting out, many an awkward and embarrassing delay on the road will be avoided.

The matter of physical comfort while on the road is of importance, and in order that the greatest degree of comfort be obtained the saddle should be placed fairly low and not too far back. The handlebars should be high enough to avoid the necessity of stretching or bending forward, and the bars should be so shaped that the hands rest upon them in a position which is easy upon the wrists.

The rider should become so familiar with his machine that he can tell by the sound when it is running properly. Any unusual noise is a sure indication of something wrong, and the machine should be stopped instantly and examined for the cause. It is probable that the trouble can be located and repaired in a moment if attended to at once; but, if allowed to go on, it might easily develop into some-

thing which would cause serious injury to the machine. The motor should not run for long periods of time on the stand and should never be allowed to race unnecessarily.

No definite rules other than those which would be dictated by common sense can be given for governing the rider's conduct when on the road. A proper consideration for the rights of other vehicles, and particularly for pedestrians, should be observed, and one must, of course, take into consideration the rules in regard to speed limit which obtain in the particular locality through which he is driving. The machine should be kept under control at all times, so that it can be brought to a stop almost instantly in case of any sudden obstruction in the traffic. Also it is well not to drive too close to the vehicle ahead, as this may stop suddenly, while the one behind you may not stop, thus causing an awkward, if not serious, situation. In turning corners or in passing other vehicles, a wide curve should always be taken in order to avoid the tendency to skid, which arises from taking sharp turns at high speed. Always slow up when turning a corner.

One of the principal causes which has brought the motorcycle into disrepute is the excessive noise caused by riders opening the muffler cut-out unnecessarily. There are times when it is necessary to do this, but the use of the cut-out should never be carried to excess.

When starting on a trip which will keep the rider out after dark, the lighting system should be examined to see that it is in good condition, as it is required that the motorcyclist show a headlight and a tail light at all times after dusk sets in.

Upon returning from a ride, the motorcycle should always be cleaned before putting it away or at least as soon as possible thereafter. The longer the cleaning process is delayed, the more difficult an operation does it become. Mud which is allowed to cake upon the cooling flanges of the motor cuts off the circulation of the air and causes overheating. Oil running down from the bearings collects dirt, which is sure to work back into the bearings sooner or later and cause trouble, while the presence of mud and moisture on the machine causes rust, which soon injures the appearance of the machine, if it does not do more serious harm. In fact, cleanliness at all times and in connection with all parts of the machine is a golden rule of motorcycling, and is an investment of time which will give large returns in the satisfactory operation and life of the machine.

OVERHAULING AND REPAIR OF MOTORCYCLES

Carburetors. Probably the greatest number of calls made upon the motorcycle repair man are for the readjustment of the carburetor. This is often simply a matter of ordinary adjustment, but where the owner finds himself unable to get a satisfactory adjustment, although he has been able to do so in the past, it is usually because of some fault in the carburetor or in its control mechanism. A common source of trouble is the sticking of the auxiliary air valve, which the repair man may often cure by a drop of oil on the shaft.

In the types of carburetors where the amount of opening of the throttle valve controls some other function, as the lift of the needle valve, a great deal of trouble will be experienced by wear and subsequent play of the shaft and connections carrying the throttle valve. The action will be very erratic, depending upon which way the play happens to be when the throttle is being closed or opened; in fact, the engine may even speed up during the closing operation. The repair for this is usually a small bushing to bring the shaft back to firm alignment.

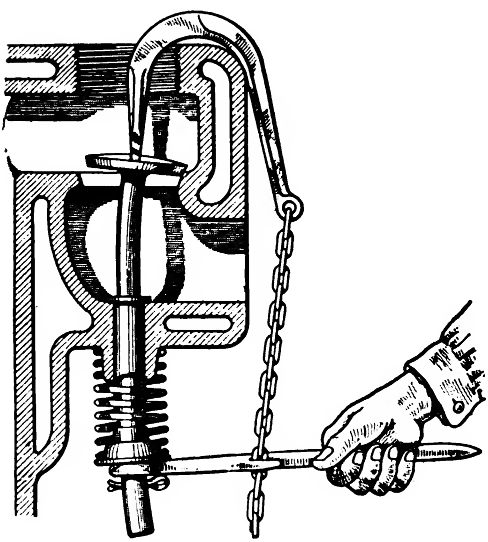


Fig. 66. Diagram Showing Bad Results from Using Valve Lifter with Too Great Pressure

When flooding of the carburetor is not caused by dirt under the float valve, it is usually a matter of a fuel-soaked float. These floats are generally made of cork, and the cure is to dry them out and recoat with yellow shellac. When the floats are made of metal, tiny pin holes, or porous places, in the soldering sometimes develop, which allow gasoline to enter and causes flooding. To discover the place of the leak, the float should be submerged in very hot water, which will

cause the gasoline to vaporize and bubble through the leaking portion. After this has been marked, a fair size hole should be punched in the top of the float, through which the entrapped gasoline may be drained out. The portion showing the leaks should then be soldered, and, after the float has cooled down, the hole in the top should be closed with solder. If this top hole is closed before the leaks are soldered, the heat of soldering will cause a partial vacuum inside the float, resulting in a seepage of gasoline through a seemingly tight float.

Valve Troubles. A great many times the carburetor and carburetor adjustment will be blamed by the owner when the trouble is from some other source. For instance, the back-firing, which is the usual indication of a lean mixture, may be caused by poorly seating inlet valves. On the other hand, the galloping of the engine, which is usually the symptom of too rich a mixture, may be due to leaking or sticking exhaust valves. On the modern machines one of the causes for faulty valve spring and valve action is very often the accumulation of dirt inside the sleeves which cover the valve mechanism. The cure, of course, in this case, is a thorough cleaning. The cure for leaking valves is a matter of grinding in.

Removing Valves. In the removal of valves the use of valve lifters has become very common, and their operation is so simple that little need be said concerning them. However, there is one warning which is worth while, particularly when using a type of lifter with which the operator is not familiar, and that is, that he does not catch the spring retaining-pin in the lower part of the lifter at the same time that pressure is being exerted upon the top of the valve, Fig. 66. The result in such a case would be a bent valve stem, which is very hard to remove.

Air Leaks in Inlet Manifold. Irregular running may be caused by air leaks at the joints of the inlet manifold. The repair man's test for this is to take the priming gun in the gasoline tank and squirt a good quantity of fuel around all the joints. If these joints leak, the engine will die from an over-rich mixture. The same galloping effect that was noted from the poorly seating exhaust valve also may be caused by weak exhaust-valve springs.

When an engine is cold, a certain amount of clearance must be left between the top of the tappet and the valve stem. This is in order that the valve may expand upon heating up and still not ride

upon the tappet, which would cause a poor seating of the valve. So far as wear upon the cam and upon the valve mechanism is concerned, it is fortunate that the motorcycle rider is not the fiend for silence that his cousin, the automobilist, has become. For this reason, the valves are set with plenty of clearance, .008 of an inch being good practice. In some cases the design is such that the cylinder actually lengthens more than the valve, owing to the heat of running. In such a case the tappet clearance would be increased instead of decreased upon warming up, and the noise would probably be excessive. Such engines, of course, may be adjusted much closer than the figure above

Fig. 67. Handling Tappet Nuts with Two Wrenches
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

given. Both the owner and the repair man should have a set of feelers and also two wrenches of the size of the tappet nuts, Fig. 67, so they need not be forced to use a bicycle wrench for making these adjustments. With air-cooled motors, it is surprising how often the tappet clearances have to be checked up for good results.

Overhauling. Where an overhauling job is on hand, the first thing, of course, is the stripping of all connections between the engine and the frame of the machine. In the repair shop, it is usually handiest to do all the overhauling work on the bench; therefore the whole engine is at once removed from the frame.

Valves. The scraping of carbon and the grinding of valves go, as a matter of course, with every overhauling job; and, where the majority of the work is with one make of machine, considerable time may be saved in grinding in the valves by having a dummy valve seat. It has been found, particularly in the case of badly-pitted exhaust valves, that it takes a much longer time to obtain a satisfactory surface on the valve itself than it takes on the cylinder seat, and, therefore, this dummy will save the unnecessary cutting down of the motor casting. The dummy may be made of cast iron, from a special pattern, or it may be a portion of an old damaged cylinder. Another thing used by one of the large motor-car companies, and justifiable only where a great many machines of the same make are worked upon, is to have made up a special seating reamer that will give a convex surface rather than a flat conical one to the seat in the cylinder. The advantage claimed for this is, that it takes less grinding to obtain a gas-tight joint, and that the pounding action of the valve tends constantly to widen the seat. Some valves are designed with a flat instead of conical seat, but the grinding process is the same.

Piston Pins. Whenever the engine is down, the repair man should not fail to look at the fastening of the piston pin to see whether there is any trouble in that direction. A piston pin which comes loose and works sideways will act exactly like the tool in a shaper, cutting a broad groove down the side of the cylinder. As a general rule, the piston-pin bearings are bronzed bushings, and, although wear at this point is not commonly excessive, poor lubrication or very great mileage will produce play. This causes a knock which is very often mistaken for a piston slap. The remedy, of course, is a new bushing or, very possibly, both a bushing and a pin.

Big-End Piston Bearings. At the lower end of the rod, the big-end bearings in the large twin machines are usually of the roller type, and when these give trouble, new sets of rollers have to be fitted. In case it is simply a matter of wear from long service, slightly oversized rollers are used. This particular job is one requiring unusual care and skill, and the repair man should be absolutely certain that the rod can be spun on the shaft for any length of time without the rollers climbing or jamming owing to the presence of some of slightly different size. In some of the older machines, bronze bushings were used for the big-end bearings and these, of course, are much more easily renewed.

Gaskets and Washers. It has been found that it does not pay to try to use any of the old gaskets in putting the job back together, as

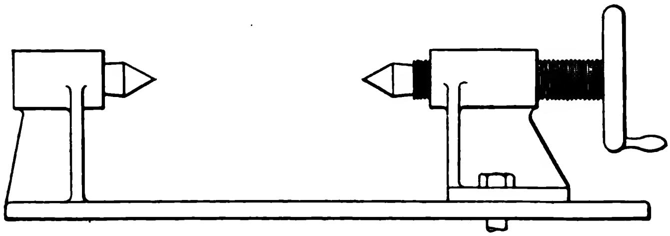


Fig. 68. Set of Centers Made up for Handling Crankshafts

they are almost sure to leak. New felt washers at the crankcase should also be used, even though the old ones seem in pretty fair

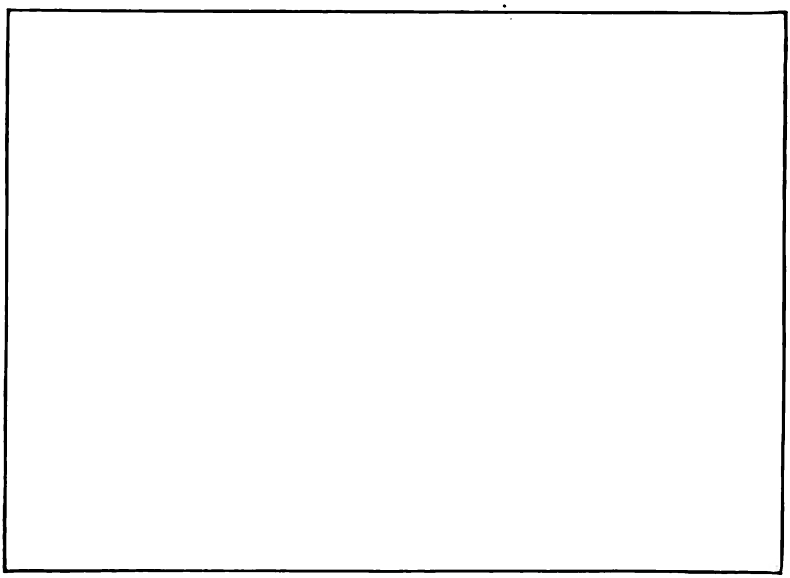


Fig. 69. Method of Marking Timing Gears
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

shape, for, before another overhauling, it is more than likely that the old ones will begin to leak oil.

Truing up Crankshafts. When the built-up type of crankshaft and the double flywheel have been torn down, for the fitting of new

bearings or for some other purpose, it is practically sure to be out of true when reassembled. In some cases, a line is marked upon the surface of both flywheels, and the truing is done by placing the crankshaft ends on blocks and striking with a soft hammer until a steel straightedge may be laid across the flywheels so as to exactly coincide with the two lines and show no light underneath on the flywheel surfaces. An even better way of truing the assembly is to have made up a set of centers, similar to Fig. 68, and, by the use of a machinist's gauge discover where the crankshaft is out of true. It is then straightened by the hammer method. In the first case, it is really the flywheels that are being trued, while in the second case, it is the more important shaft itself. Before the truing operation, the nuts may be drawn up good and snug; but, after the truing is done, it is found that they can be drawn still tighter.

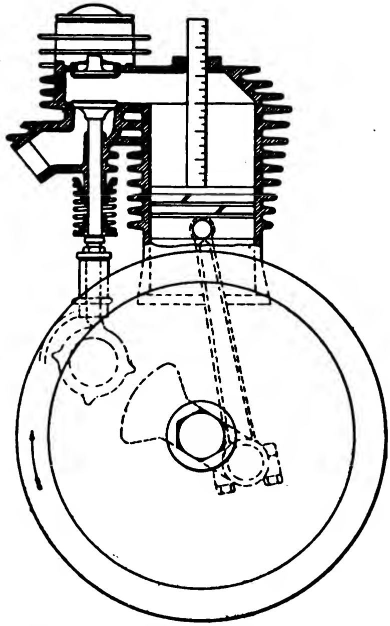


Fig. 70. Method of Following Out Valve Timing by Means of Scale

Valve Timing. *Marking Gears.* In a complete overhauling job, it is more than likely that the timing gears have been removed for cleaning and inspection, in which case the engine has to be re-timed upon assembling. It is usual for the manufacturer to place marks, in the form of little cuts or prick-punch centers, on the gears, Fig. 69, so that they may be replaced in the proper manner. One method is to prick-punch each set of teeth while under some certain conditions, such as at the point of closing of the exhaust valve. Another method is to line up certain marked teeth with marks made in the back wall of the gear case. It sometimes happens that the manufacturer's marks are not found, and a new set of marks is put on by the repair man before disassembling the job. At a later date, both sets of marks may show up, with a resulting confusion. It is well, then, to know something of the valve timing, instead of having to depend blindly upon the marking of the gears.

Opening of Valves Not on Dead Center. In the discussion of the principle of operation of a four-cycle engine, one would be led to believe that the inlet valve opened exactly on upper dead center and closed on lower dead center, while the exhaust valve had an opposite performance. This is theoretically true; but practice has shown that, owing to the inertia of the flow of gases and other little-known conditions within the engine, the valve timing can be changed considerably from the dead center points, giving marked improvement in the power output of the engine.

Marking Flywheels—Automobile Practice. In automobile practice, it is customary to speak of valve timing in degrees on the crankshaft circle, and the openings and closing of the valves are usually laid off and marked upon the rim of the flywheel. Since in most of the motorcycles the flywheels are enclosed, this method is not employed, and where the maker furnishes information as to the valve timing, it is in terms of the travel of the piston from the upper or from the lower dead center, as measured in inches.

Getting Valve Timing with Scale. Where the cams are all made integral, only one point of the timing can be controlled, the other points being in a fixed relation, the accuracy of which depends upon the workmanship in the cam-grinding department. Since the closing of the exhaust and the opening of the inlet is important for smooth running, this is the point that is taken for setting the valves. Fig. 70 shows a very easy method of following out the valve timing. A scale is dropped through one of the openings in the top of the cylinder, possibly the spark-plug hole, and, after the dead-center points have been noted, the crankshaft is revolved until the scale shows that the piston has moved down or up the desired distance from dead center. With the crank at this point, the gears are slipped into mesh so that the valve will be just opening or closing, as the case may be.

In some cases, the inlet and exhaust valves can be timed separately. Owing to the inaccuracies in grinding, one seldom can obtain both the opening and the closing points stated by the manufacturer. It is best, therefore, to set the timing on the closing of the exhaust and the opening of the inlet, letting the opening and closing, respectively, take care of themselves.

The following timing instructions are taken from the instruction book of a well-known maker and are illustrative of the form:

Twin-Cylinder Motor

The exhaust valve should open when the piston is $\frac{5}{8}$ inch to $\frac{3}{4}$ inch before bottom center and should close $\frac{1}{32}$ inch to $\frac{1}{16}$ inch after top center. The inlet valve should open $\frac{1}{16}$ inch to $\frac{3}{32}$ inch before top center and close $\frac{1}{8}$ inch to $\frac{1}{4}$ inch after bottom center. With advanced spark, the motor should fire $\frac{1}{4}$ inch to $\frac{5}{16}$ inch before dead center. Time each cylinder separately as the interrupter housing steel segments are often out of line

Single-Cylinder Motor

The exhaust valve should open $\frac{5}{8}$ inch to $\frac{3}{4}$ inch before bottom center and close $\frac{1}{32}$ inch to $\frac{3}{32}$ inch after top center. The inlet valve should open on dead center and close $\frac{1}{4}$ inch to $\frac{3}{8}$ inch after bottom center. The spark timing is the same as that of the twin.

Oily Clutches. The dry clutches with alternate discs covered with a woven fabric of asbestos and brass or with copper wire give considerable trouble from slipping, owing to the presence of grease or to the glazing of the surfaces. When grease is the cause, the clutch is disassembled and washed in gasoline. One shop takes the plates and piles them in pairs and then sets fire to pieces of oil-soaked waste, shown in Fig. 71, in order to completely burn out all the grease. The surface is then roughened up with coarse emery cloth and chalked, after which the clutch is again assembled. The chalk is for the purpose of soaking up the grease and of giving a fairly harsh engagement. In case the trick has been overdone, a little engine lubricating oil squirted into the clutch will make the engagement easy again.

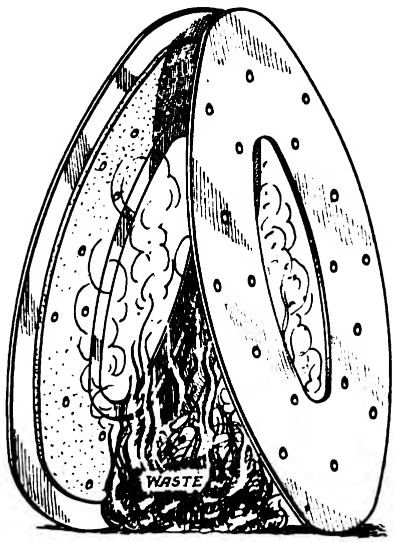


Fig. 71. Burning Oil Off Clutch Discs

The most clutch trouble has come when a side car has been added; and in one case the makers provided for this by so designing the clutch that the usual equipment of eight springs could be increased by eight when a sidecar or a delivery van was attached to the machine. This makes the clutch action suitable under all kinds of service. Most motorcycle clutches, whether of the cone or of the disc type,

have more than one clutch spring—usually three or five. It is of very great importance, therefore, in adjusting one of these clutches, to give the nuts on each spring exactly the same number of turns, otherwise the action will be very unsatisfactory and the clutch liable to serious damage. On some of the older cars with belt drive, the clutch has been accused of slipping, when, in truth, the trouble was with the belt. This resulted in continued adjustment of the clutch, until the

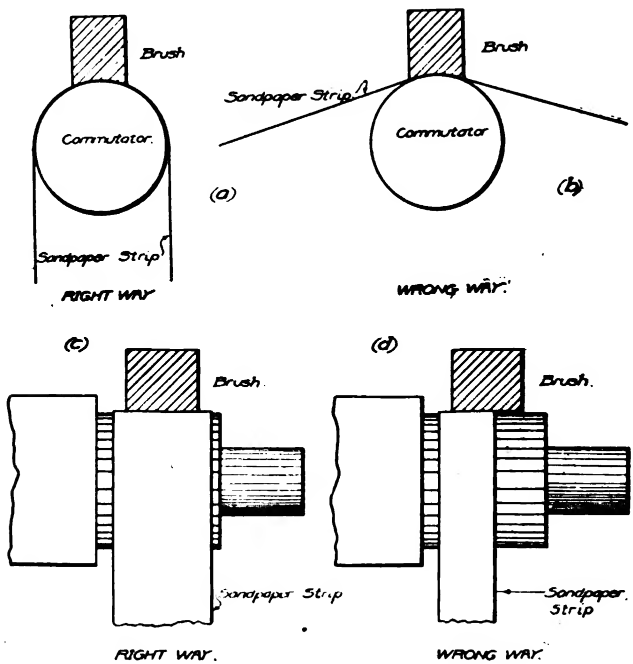


Fig. 72. Method of Sanding-In Brushes

load imposed upon the thrust bearing was so great that it went to pieces.

Cleaning Chains. A roller chain and set of sprockets is a highly efficient transmission unit when kept in good condition, but not otherwise. One or more times during a season, depending upon the mileage, the chains should be removed, cleaned well in gasoline or kerosene, and then let soak over night in oil. The next day, they should be hung up to drip until they are dry. There is no use trying to hurry the oiling process, as the object is to let the lubricant work into the small bearings between each pin and roller.

Although chains and sprockets are laid out by the designers, with such a number of teeth that the one particular link of the chain will be a long time reaching a particular tooth for a second time, it does sometimes happen that the wear is not evenly distributed. In such a case, a chain which was satisfactorily quiet and apparently having considerable service left in it will be found noisy, or will bind when replaced after the overhauling. As a matter of precaution before their removal, therefore, it is not unwise to mark, in some way, the position of the chains in relation to the sprockets and to return them to the same location after the cleaning process.

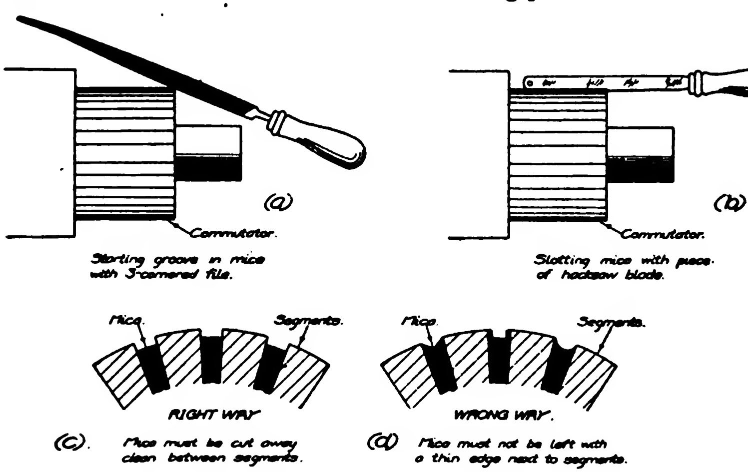


Fig. 73. Method of Undercutting Mica Insulation on Commutator

Dirty Muffler. There is one unit of the machine which the careless repair man or the amateur may neglect to go over in the overhauling job, and that is the muffler. This is a grave mistake, for an air-cooled motor naturally burns a good deal of cylinder oil; and it will be found that after a season's running the muffler will be pretty well choked up with carbon. With an engine which has been burning an excessive amount of oil, there may even be an accumulation of carbon and oil in the muffler, which will be of the consistency of wet cement. These conditions produce a back pressure upon the engine, which cuts down the power no matter in what mechanical condition the engine may be. It is the allowing of dirty mufflers that probably causes so many riders to annoy the public with the use of the muffler cut-out. If the muffler is clean and clear, there is really no excuse for

the cut-out except in testing for engine operation, for, under these conditions, the difference in power attained is almost negligible.

Electrical Troubles. Electrical troubles may be classified under two heads: short-circuits and open circuits. In the first case, there is a path back to the generator or storage battery before the current has reached the desired point. This is usually due to chafed installation or to a loose strand of wire. The open circuit means a break in the path of the current and often occurs at the point where the wire enters the connection to a lamp, a horn, etc.

Short-Circuits and Open Circuits. A serious short-circuit will blow the fuse, and there is no object in replacing it with a new fuse until the point of trouble has been found, as the new fuse will, in turn, be blown out. A trouble lamp may be inserted in the fuse block, as shown in the Excelsior diagram, Fig. 55, and as soon as the difficulty is found, the lamp will go out. The open circuit is usually easier to trace, as the lamp or the horn in that circuit will fail to work, while the rest of the system will be in good order.

Lubrication of Electrical Equipment Requires Care. Over-lubrication of a generator is a serious matter, for if oil works its way into the windings, it is liable to soften the installation and also to cause other damage. On the other hand, all bearings must be lubricated, particularly those running at the high speed that armature bearings do.

Care of Brushes. In time, the brushes may need dressing and the armature brightening up. Fine sandpaper can be used for this purpose, as shown in Fig. 72. Emery cloth should never be used on the brushes or the armature of a generator, as emery is a conductor of electricity, and if it becomes embedded between the commutator segments, it will cause a short-circuit in the armature. After long service, the mica installation between the commutator bars may need dressing down, and the method of doing this is shown in Fig. 73.

Storage Batteries. So far, the demand for storage-battery work on motorcycles has not become extensive enough for many motorcycle repair shops to put in a battery charging and overhauling department. Many shops will probably do so soon, as the number of electrically equipped machines keeps increasing and small-capacity charging sets are being developed. At present, the regular battery service stations are best equipped to handle all major battery work.

WELDING IN AUTOMOBILE REPAIR SHOPS

INTRODUCTION

Welding Field. The welding process is undoubtedly one of the greatest contributors to the efficient and economical manufacture of the modern automobile. It has made possible higher standards of body design and may be given almost exclusive credit for the light weight and great strength of the present-day motor car, producing stronger and better working parts through the use of pressed steel instead of the heavy castings or riveted parts, such as axle housings, Fig. 1, and manifolds, tanks, bodies, etc., Fig. 2.

In the field of automobile repair it is rapidly assuming an equally important place, affording a quick and inexpensive means of permanent repair to parts no longer obtainable from the supply house or manufacturer and permitting the building up of weak parts or the altering of the chassis, as may be required. This great adaptability of the welding unit has made it an essential part of the equipment of every efficiently managed repair shop.

WELDING PROCESSES

Old and New Methods. The old systems—blacksmith, or forge, welding, and brazing—are now seldom used in automobile work. In fact, most blacksmiths have equipped themselves to do welding in the modern way, using it almost exclusively for their repair work because it is cheaper, simpler, more efficient, and can be used on materials which could not be welded by means of the old-style methods. The modern systems of welding include the flame and electric processes. Because it is almost universally used in repair shops, the flame process and the apparatus required in its use will be discussed first. Several flame-welding processes have, from time to time, been introduced, all utilizing oxygen in combination with some fuel gas, such as acetylene, hydrogen, city gas, natural gas, liquid gas, Blau gas, carbo-hydrogen, thermaline, etc. Many enthu-

Fig. 1. Oxy-Acetylene Welding in Manufacture of Rear Axle Housings

Fig. 2. Oxy-Acetylene Welding in Manufacture of Automobile Bodies

siastic claims of superiority have been made for each of these combinations by their advocates.

OXY-ACETYLENE PROCESS

Advantages. The easy control and intensity of the heat developed by the oxy-acetylene flame (approximately 6300° F.) and the adequate supplies of carbide and dissolved acetylene which are maintained in every industrial center in the United States have proved the greater desirability, economy, and efficiency of the oxy-acetylene process.

Another factor which has contributed largely to the popularity of the oxy-acetylene process is the comparatively inexpensive apparatus required and the low cost of its operation. Its speed, portability, and the ease with which its method of operation may be learned by any intelligent workman make it especially well fitted to the need of the automobile repair shop. Very seldom is any extensive dismantling of parts necessary in making an oxy-acetylene repair and, for this reason, it simplifies greatly the work of the repair man.

Gases. As is generally known, two gases are used in the oxy-acetylene process—oxygen and acetylene.

Oxygen. Oxygen is manufactured from air by liquefaction or from water by electrolysis. The former method is by far the greatest source of supply, furnishing practically all the oxygen used in this country and abroad. Oxygen made by the liquid-air process can contain only an impurity such as nitrogen, which cannot possibly do any harm. On the other hand, oxygen made by the electrolytic method contains some hydrogen, which will render it dangerous to handle if more than two per cent is present.

Because of the very high cost of an oxygen plant and the ease with which an adequate supply of compressed gas may be obtained from manufacturers' supply stations, it has been found impractical for even the largest consumers to attempt the manufacture of their own oxygen.

Almost everybody is familiar with the appearance of the oxygen cylinder, shown at the right in Fig. 3, which plays so important a part in present-day manufacturing. These steel cylinders contain 100 or 200 cubic feet of gas compressed to a pressure of 1800 pounds per square inch. They are furnished to the consumer without charge,

the customer paying only for the oxygen and returning the cylinder to the manufacturer when the gas has been exhausted.

Acetylene. The acetylene may be obtained in cylinders, shown at the left in Fig. 3, containing 100 or 300 cubic feet, or, where large quantities are required, it is generated on the premises. Though frequently referred to as compressed, the acetylene in cylinders is really not compressed, but is dissolved in a solvent which has the property of absorbing many times its own volume of acetylene as pressure is applied. This liquid in which the gas is dissolved in no way affects the flow of gas except when the acetylene is drawn off from the cylinder at too rapid a rate. Experience has proved that when the gas is used at a rate greater than one-seventh the capacity of the cylinder per hour, the solvent is very likely to travel with the acetylene, lowering the temperature of the flame and thus hindering the work. To overcome this difficulty, where it is necessary to supply gas at a greater rate, several cylinders may be coupled to a manifold, or header, so that the total capacity is at least seven times their hourly discharge.

Fig. 3. Welding Unit for Use with Acetylene in Cylinders, Mounted on Emergency Truck
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

Generators. By means of the acetylene generator it is possible to produce pure acetylene at less than half the cost of dissolved acetylene, so that if any considerable work is to be done a generator will pay for itself within a few months or a year. In these generators small quantities of calcium carbide are automatically fed into a large

Fig. 4. Low-Pressure Acetylene Generator
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

quantity of water, producing the gas at just the rate required by the work in hand.

There are two recognized systems of generating acetylene—the low-pressure system and the pressure system.

Low-Pressure Generator. This type of generator, Fig. 4, delivers acetylene to the blowpipe under a pressure of less than one pound. This system has the advantage of maintaining at all times an abso-

lutely constant pressure, which is an essential requirement. The carbide feed is controlled by the rise and fall of the gas bell, in which the pressure is always the same, without the use of any pressure-regulating device.

Pressure Generator. The pressure generator, Fig. 5, delivers acetylene at a pressure of more than one pound. The carbide feed is controlled by the pressure in the generator. As the acetylene is drawn off and the pressure decreases, carbide is fed into the water;

Fig. 5. Portable Pressure Acetylene Generator
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

this generation of gas increases the pressure and the feeding stops. In order to compensate for this pressure variation, a pressure-diaphragm regulator, or reducer, is necessary so that the acetylene may be supplied to the blowpipe at a constant pressure.

The low-pressure generator furnishes the most satisfactory service under average conditions, though where portability is essential, pressure generators of compact construction may be obtained to meet this need.

Welding Blowpipes. There are two types of oxy-acetylene welding blowpipes, namely, the low-pressure, or injector, type and the equal-pressure type.

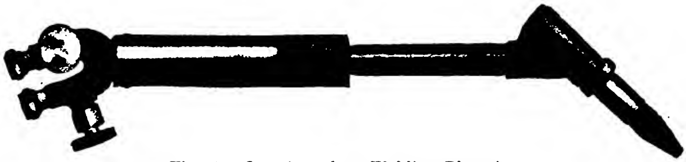


Fig. 6. Oxy-Acetylene Welding Blowpipe
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

Injector Blowpipe. In the injector type, Fig. 6, the acetylene is delivered to the blowpipe at a pressure of only a few ounces. The oxygen at a higher pressure passes through the injector, Fig. 7, and expands rapidly into the mixing chamber. This rapid expansion and high velocity of the oxygen form a suction and draw in the acetylene at a constant ratio. A slight variation in pressure of either

Fig. 7. Section of Injector-Type Blowpipe

the oxygen or acetylene is automatically taken care of by the injector, so that a neutral flame is maintained at all times.

Pressure Blowpipe. In this blowpipe the acetylene is used at almost the same pressure as the oxygen. The oxygen enters the mixing chamber at the rear and the acetylene through a couple of holes at the side.

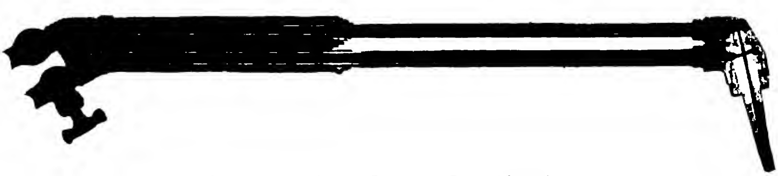


Fig. 8. Section of Pressure-Type Blowpipe

In the injector blowpipe the rapid expansion into the tapered mixing chamber sets up a whirling action and produces an intimate mixture of the oxygen and acetylene so that a ratio of 1.05 parts oxygen to 1.00 part acetylene is obtained, which is almost the theo-

retical or perfect ratio of 1.00 to 1.00. In the pressure blowpipe there is no means of obtaining such an intimate mixture of the gases in the mixing chamber; Fig. 8, which in most cases is not tapered, and consequently about the best ratio obtainable is 1.14 to 1.00. This larger amount of oxygen is, of course, wasted and, besides, tends to produce an oxidized weld. It is the surface oxidation, or burning, of the molten metal that leads some operators to believe that they are welding fast, while in reality they are only burning the surface and are not fusing the metal underneath.

Oxy-Acetylene Flame. The oxy-acetylene flame is the hottest flame obtainable. Its temperature of 6300° F. is 2000 degrees above that of any of the other flames. This high temperature allows the work to be done quickly and with only a very slight loss of heat due to conduction and radiation.

There are three phases of the oxy-acetylene flame, Fig. 18, namely, the neutral, or welding, flame; the carbonizing, or reducing, flame; and the oxidizing flame. Each of these has its characteristic appearance and it takes only a little practice to instantly recognize them. The appearance of these will be taken up later under "Flame Regulation", page 25.

Expansion and Contraction. These natural changes of the work, due to the heat of the welding, are taken care of in the case of rolled or forged materials by proper spacing of the edges or by holding the work in suitable jigs and, in the case of castings, by proper pre-heating and cooling. The most satisfactory methods of handling this feature will be taken up under the instructions for welding various materials.

Preparation of the Work. This is a very important feature and should receive the operator's best thought and effort. A fair amount of reasoning and planning on the part of the operator before he attempts a job will save considerable time and keep the cost of the welding low. The operator should figure out several ways and means of handling the particular task at hand, and should then select the best. This applies especially to castings, such as crankcases and cylinders, which may be welded perfectly if the operator uses good judgment but which will be ruined if he does not.

Welding Rod. Thin plates may be welded by bringing the edges into contact and fusing them together. For heavier work, the edges are beveled to form a groove, and a filling material, or "welding-

rod", is fused into the groove. In most cases a material similar to the work being welded is used. The operator may build up the weld by means of the welding rod so that the section at the weld is greater than the section before welding, thus insuring a strength even greater than the rest of the piece.

Flux. A suitable flux is used in cast iron, aluminum, brass, copper, etc., welding to dissolve any impurities and to give a film, or protecting coating, to the fused material to prevent oxidation.

Both the welding rod and the flux used are extremely important factors in the welding and should be obtained from a reliable manufacturer who supplies only materials that are tested and analyzed to determine their purity and suitability for the work.

Strength of Weld. With proper equipment and suitable rods and fluxes, the strength of the weld will depend mainly upon the skill

Fig. 9. Oxy-Acetylene Cutting Blowpipe
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

and care of the operator. An operator who has had considerable experience and who is careful with his work should be able to obtain as high as 95 per cent the strength of the original material, although 85 per cent may be taken as a safe lower limit for the average good welder.

Working and Hammering. If the weld is hammered when at the proper temperature, its strength will be increased, in the case of welds in steel, by making the grain of the material finer.

Experience of Operator. Poor work due to carelessness or inexperience of the operator, poorly designed and cheaply constructed apparatus that is not capable of handling the work, may be held responsible for such failures as may occur in the oxy-acetylene process.

The handling of the process is not difficult and, therefore, some operators undertake difficult jobs before they are sufficiently capable or experienced. When such a job fails, it is but natural that both the

customer and the operator should blame the process rather than the way in which the work was handled. Time may be very profitably spent in practice on scrap material before undertaking work on materials with which the operator is unfamiliar. By thus laying the foundation for a satisfactory result, the operator may quickly develop

Fig. 10. Electric Spot-Welding Machine
Courtesy of Thomson Spot Welder Company, Cincinnati, Ohio

his skill to the point which will bring him the confidence and patronage of a constantly increasing number of customers.

Oxy-Acetylene Cutting. Cutting by the oxy-acetylene process is done by means of a separate blowpipe, Fig. 9, quite different in construction from that used for welding. A more detailed description of the cutting process is given on page 77.

ELECTRIC PROCESSES

Methods. For a number of years electric welding was used as a laboratory experiment, but recently the process has been more fully developed. Two distinct methods are utilized: one, the electric-resistance welder, or spot-welder, Fig. 10; and the other, the electric-arc welding machine, Fig. 11.

Spot-Welder. The electric-resistance welding process provides for the passage of a heavy current through the joint between the pieces to be welded, allowing the resistance of the bad contact to heat them locally until they are soft enough to stick together; squeezing

Fig. 11. Portable Arc-Welding Outfit
Courtesy of C & C Electric and Manufacturing Company, Garwood, New Jersey

the pieces while soft will then cause them to adhere. This process is used mostly in making light automobile parts, such as mud guards, bonnets, etc., rather than for repair. It is also used to some extent instead of small rivets in light sheet-metal work and for spotting, or tacking, small parts together preparatory to welding them with the oxy-acetylene flame.

Arc Welder. In order to do welding with the electric arc, after suitable equipment has been provided, it is necessary to first connect the work to the positive side of the power-supply circuit and the welding electrode to the negative side of the circuit by means of wires or cables, with the regulating devices in circuit to control the amouut of current flowing. The negative electrode is then placed lightly in contact with the work and quickly withdrawn to make the circuit

Fig. 12. Operator Using Metallic Electrode
Courtesy of C & C Electric and Manufacturing Company, Garwood, New Jersey

and draw the arc, thus providing the high temperature required for welding.

Electric-arc welding usually consists in using the heat of the arc to fuse, or melt, the filling material into the place to be filled, although the article worked upon may be melted down sufficiently to fill the space if it is large enough at the point to be welded.

Two methods, or processes, using the arc for welding, are in commercial use, these being the metallic and the graphite, or carbon, processes.

Metallic Electrode. The metallic welding process consists in using a piece of wire of the proper kind as the negative electrode of the arc and fusing it into place, drop by drop, Fig. 12.

Graphite Electrode. The graphite process consists in using a piece of graphite, or carbon, as the negative electrode and fusing a piece of metal into place by the heat of the arc.

Apparatus. It is possible, though not practical, to do electric-arc welding, having nothing but a source of primary current, and some

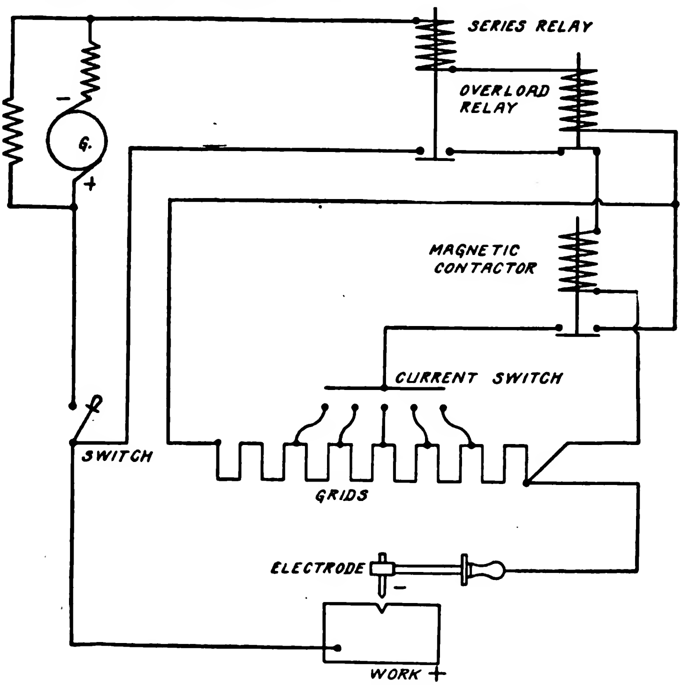


Fig. 13. Wiring Diagram for C & C Welding System

means for regulating the amount of current flowing, but the use of resistance only as a means of regulating the amount of current flow is so wasteful that other apparatus must be used for the sake of economy. It is well known among electrical men that a motor-generator set gives the best regulation of voltage, therefore, the leading arc-welding outfits in use today consist of a motor-generator set with suitable rheostats, resistances, circuit-breakers, fuses, indicating instruments, and switches for controlling the motor-generator and welding circuits, Fig. 13.

From the foregoing description, it will be surmised that an electric-arc welding equipment will be too expensive in initial cost for the average auto repair shop. However, it finds a useful field in the welding of very heavy work where there is sufficient volume of it to justify the investment.

TECHNIQUE OF OXY-ACETYLENE WELDING

SIMPLE WELDING JOB

Apparatus Required. The material in the following paragraphs must not be considered as instructions for welding but merely as a brief discussion of the various steps in making a simple weld. Complete instructions for connecting and operating the equipment are given in detail later. In general, the following equipment is needed for every welding job, no matter how small:

(a) A welding blowpipe
(b) A supply of oxygen
(c) An oxygen regulator
(d) A supply of acetylene
(e) An acetylene regulator
(f) Hose to connect blowpipe to oxygen and acetylene supplies

Preparing the Metal. First, the edges of the two pieces of metal to be welded are chamfered or beveled, so that when they are placed together the two beveled edges form a V, the width of the V being about equal to the thickness of the metal.

Next, the two pieces are placed together on a flat surface of fire brick, or other nonconductor of heat, so that the edges just touch at the bottom of the groove. This gives the line of the weld. The two pieces are then ready to be welded as soon as the apparatus is connected.

Connecting the Apparatus. To connect the apparatus, the following steps should be taken:

(1) The oxygen regulator is connected to the oxygen cylinder.
(2) The acetylene regulator is connected to the acetylene cylinder.
(3) The one hose is connected to the oxygen regulator and to the blowpipe.
(4) The other hose is connected to the acetylene regulator and to the blowpipe.

(5) A welding head is selected and attached to the blowpipe.

(6) The oxygen and acetylene are turned on and the blowpipe is lighted.

Welding. The operator is now ready to weld. He takes the lighted blowpipe in his right hand, Fig. 14, and plays the flame upon the beveled edges of the two pieces of metal to be welded. The intense heat of the flame melts the edges and they flow together. As

Fig. 14. Simple Job of Welding

the edges flow together, the operator melts in new metal from a rod which he holds in his left hand, so that the entire groove is filled up, producing a perfect union or weld.

When the entire groove has been filled in this manner, the operator turns out the blowpipe, and allow the metal to cool.

The foregoing is a brief outline of the steps taken by an operator in performing a simple operation of welding two small pieces of steel.

We will now take up these different steps and will give more specific and detailed descriptions of the welding apparatus and complete instructions in its operation and use.

OPERATION AND CARE OF WELDING APPARATUS

Necessity for Care. It is proper that in the operation of the welding apparatus we should lay stress upon the importance of careful and orderly methods in the handling of such apparatus. It should be borne in mind that the regulators and gages are sensitive measuring devices, that in the blowpipe the orifices are carefully designed and accurately machined to permit the passage of a definite quantity of gas and, therefore, that rough usage and abuse will certainly decrease their efficiency. It is not necessary in this place to give detailed instructions for the operation and care of the various makes of apparatus, because these are invariably furnished by the manufacturers with their equipment.

Because of the fact that dissolved acetylene is most generally used in garages and small job shops, we will confine our explanations to the use of apparatus with cylinder equipment. Owing to the greater simplicity of handling, however, the operator will have no difficulty in making use of generated acetylene when the opportunity arises.

Necessary Welding Apparatus. A complete welding station, Fig. 15, for use with acetylene dissolved in cylinders, consists of the following apparatus:

Welding blowpipe *G* with set of welding heads
Oxygen welding regulator *C* with two gages
Acetylene regulator *D* with one or two gages
Adapter *L* for acetylene cylinder
Two lengths high-pressure hose *E* and *F*
Darkened spectacles, wrenches, hose clamps, etc.

Welding Blowpipe. The two types of welding blowpipes were described on pages 7 and 8, and need no further explanation as to the principles of operation. They are furnished by the manufacturers in various lengths to take care of various classes of work, from short light-weight blowpipes less than a foot long for light sheet-metal work up to blowpipes several feet long, which allow the operator to stay away from the intense heat as far as possible when working on heavy jobs.

Welding Heads and Tips. About ten sizes of welding heads, or tips, are supplied for use on different thicknesses of metal and various classes of work, each giving its own special size flame. The

oxygen consumption of the various size heads ranges from about 4 to 70 cubic feet per hour. In some makes the heads are made of one

Fig. 15. Complete Welding Station

piece, while in others they consist of a brass or bronze body and a copper tip, which can be easily and cheaply replaced when necessary.

Working Pressures. The necessary pressures of the gas that are required by the different size welding heads are given by the manufac-

turers, and it is very important that the operator use only the pressures recommended if he wishes to get the best economy and the strongest weld possible. Some operators believe that by increasing the pressure above that specified by the maker of the apparatus that they are able to do the work more quickly and easily. This idea is wrong, because when the pressure is increased, the larger volumes of oxygen and acetylene cannot mix as well, so that oxide forms in the weld and has to be removed. This takes more time and is very likely to leave a slightly oxidized and weak weld.

If the welding head being used is not large enough, use a larger size; never try to increase the ability of the smaller head by increasing the pressure.

It is equally bad to use a pressure that is too low. If this is done, continual back-firing will result.

Care of Blowpipe. If the blowpipe is handled properly there will be very little deterioration. It should only be necessary to clean the replaceable and working parts and occasionally ream out the tips. The tips should never be reamed out with any instrument other than a copper or brass wire having a long taper. Care should be taken that the orifices of the tips are not enlarged by reaming. If they become enlarged, they may be closed slightly by placing a conical swag over the end and tapping lightly with a hammer. The end of the tip should then be dressed off square by means of an extra fine file, and the orifice trued round by reaming with a twist drill of the proper size.

Fig. 16. Cleaning Blowpipe by Means of Oxygen under Pressure

The blowpipe may be cleaned by removing both the acetylene and the oxygen hose and connecting the tip to the oxygen hose, Fig. 16, and turning on the oxygen to a pressure of about 20 pounds per square inch, having the *acetylene* needle valve *open* and the oxygen needle valve closed, so as to drive any obstructions through the larger acetylene passages of the blowpipe. Then close the acetylene valve and open the oxygen valve to clean out the oxygen passages.

Regulators. There are various types of regulators on the market today, but the most successful ones are very similar in design and construction. The principal parts of a constant-pressure regulator, Fig. 17, consist of the body proper, regulator valve, diaphragm, pressure-adjusting spring, safety-relief valve, and gages.

The diaphragm may be either special reinforced rubber sheeting or phosphor bronze. The former is preferred, because it is less likely to crack, or split, is more readily replaced, and gives more sensitive regulation because of its finer elastic properties.

Fig. 17. Section of Pressure Regulator
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

Operation of the Regulator. Gas passes from the cylinder valve through the passageway to the regulator valve. The pressure overcomes the tension of the inner spring and moves the sleeve-piece toward the back of the regulator, opening the valve. This allows gas to pass into the diaphragm chamber and out of the regulator by way of the hose connection. As the pressure in the diaphragm chamber increases, the tension of the pressure-adjusting spring is overcome, the diaphragm deflects, the sleeve-piece moves forward, and the valve

closes partly or all the way. Then, as gas passes out of the regulator and the pressure in the diaphragm chamber decreases, the tension of the pressure-adjusting spring and the pressure of the gas entering the regulator move the sleeve-piece backward, admitting more oxygen to the regulator. The pressure in the diaphragm chamber builds up as before, the diaphragm deflects, the sleeve-piece moves outward, and the valve closes.

Oxygen Welding Regulator. This is an automatic regulator which is especially designed for welding operations. It is connected to the oxygen cylinder and is designed to deliver oxygen to the blowpipe at any uniform pressure at which the regulator is set. To do successful welding, the oxygen regulator must be as nearly perfect as it is possible to construct it. This device is required to reduce a pressure which may be as high as 1800 pounds per square inch in the cylinder and which is constantly varying, down to a pressure from 10 to 30 pounds per square inch; at the same time the regulator must keep the lower pressure constant.

Oxygen regulators are usually equipped with two gages. The high-pressure gage shows the pressure of the gas in the cylinder and may be used to determine the amount of oxygen in the cylinder (see under Measuring Oxygen, page 99). The low-pressure gage shows the operating pressure at which the oxygen is being supplied to the blowpipe.

Acetylene Regulator. The acetylene regulator is used with acetylene supplied in cylinders. It is connected to the acetylene cylinder adapter, and this to the acetylene cylinder. The acetylene regulator is designed to deliver acetylene at a uniform pressure, as needed by the blowpipe.

Acetylene regulators are usually equipped with a large gage that shows the pressure in the cylinder, but which cannot be used to accurately determine the contents of the cylinder (see Measuring Acetylene, page 102). A small gage is not necessary with the low-pressure, or injector, blowpipe, because the acetylene pressure required by this type of blowpipe is very low—only a few ounces. With the pressure blowpipe, however, a small gage is necessary, because it is important to know that the acetylene pressure, which ranges from 2 to 13 pounds per square inch, is supplied to the blowpipe at the required pressure for the tip used.

Care of Regulators. Never drop or jar a regulator. Do not use oil, grease, or any organic material for lubrication in connection with regulator. If it becomes necessary to lubricate the pressure-adjusting screw, or to repack a needle valve, make use of a little glycerine—nothing else.

Do not allow dust to enter the regulator. Always insert the dust plug when the regulator is not in use. These are supplied with most regulators and are intended to keep dust out of the regulator when it is not in use and to protect the union nipple at the back.

Do not change the regulator from one cylinder to another without releasing the pressure-adjusting screw. The diaphragm is liable to be ruptured if there is tension on it when the sudden rush of gas takes place as the cylinder valve is opened.

Do not attempt to repair, adjust, or change the internal mechanism of the regulator, other than replacing the diaphragm and resurfacing or replacing the valve seat. Send it to the manufacturer for repairs.

Do not replace diaphragms or valve seats with any material other than that supplied by the manufacturer for this purpose.

Hose. The best hose that it is possible to obtain should be used, because it is really the most economical in the end, although it might cost more at the beginning. A good grade of two-ply hose will be found to be flexible, light weight, easy to handle, and, at the same time, will not kink easily nor be permanently flattened if heavy objects happen to accidentally fall on it. In selecting a hose, the welder should see that he gets a hose that has a finished inside surface, so that small particles of rubber and dust will not flake off and be blown into and clog the blowpipe or welding head.

It is best to use different colored hose for the oxygen than for the acetylene to prevent errors in connecting and to avoid any possible danger from interchanging.

Care of Hose. Both the acetylene and the oxygen hose should be blown out occasionally so that dirt and dust will not be carried into the blowpipe. This can be done by removing the hose from the blowpipe, connecting each in turn to the oxygen regulator, and allowing oxygen of about 20 pounds per square inch to blow through it. Examine the hose, from time to time, for leaks by immersing in water when under pressure.

INSTRUCTIONS FOR CONNECTING APPARATUS

Preliminary Operations. The following directions are given as a starting point for beginners in the operation of welding equipment. The letters given refer to the labeled parts in Fig. 15, page 17.

1. First open the oxygen cylinder valve *B* for a moment to blow out any dirt or dust which may have collected in the valve, so that it cannot enter the oxygen regulator when it is attached to the cylinder.

2. Remove the regulator dust plug and attach the oxygen regulator *C* to the oxygen cylinder *A*.

3. Connect the oxygen hose *E* to the oxygen regulator and to the oxygen hose connection on the blowpipe *G*. The hose connections are usually readily distinguished by markings on the needle valves.

4. Release the pressure-adjusting screw on the oxygen regulator by turning to the *left* until it is perfectly free.

Do not open the valve on the oxygen cylinder until positive that the adjusting screw on the regulator is fully released. The diaphragm may be ruptured and the regulator put out of commission.

5. Slowly open the oxygen cylinder valve *B as far as it will go. Not part way.*

Do not leave the valve on the oxygen cylinder only part way open. This valve seats when fully opened or closed, but is likely to leak when open only part way.

Do not handle the regulator with greasy hands nor allow any oil, soap, or organic matter to come in contact with any part of the regulator or cylinder valve. Oxygen under high pressure coming in contact with these substances is dangerous.

6. Wipe out the acetylene cylinder valve to remove any dirt or dust which may have collected in the valve, so that it cannot enter the acetylene regulator when it is attached to the cylinder.

7. Attach the adapter *L* to the acetylene cylinder *K*.

8. Remove the regulator dust plug and attach the acetylene regulator *D* to the adapter.

9. Connect the acetylene hose *F* to the acetylene regulator and to the acetylene hose connection on the blowpipe *G*.

10. Release the pressure-adjusting screw on the acetylene regulator by turning to the left until it is perfectly free.

11. Open the acetylene cylinder valve about three full turns by means of the wrench *J*.

12. Select the welding head of the size suitable for the work in hand. Screw the welding head down firmly, but not too tightly, into the head of the blowpipe with the wrench provided for that purpose.

Starting the Work

How to Light the Blowpipe. 1. Take the blowpipe in hand and open the oxygen needle valve fully.

2. Turn the oxygen pressure-adjusting screw to the right until the required pressure for the welding head being used shows on the low-pressure gage. See the maker's chart for the correct pressure.

3. Close the oxygen needle valve.

4. Open the acetylene needle valve fully.

5. Turn the acetylene pressure-adjusting screw to the right until a good jet of acetylene issues from the welding-head orifice. In the case of pressure blowpipes, turn the screw until the required pressure for the welding head being used shows on the low-pressure gage. (See the maker's chart for the correct pressures).

6. Open the oxygen needle valve slightly and light the blowpipe by means of the pyro-lighter that is usually furnished.

7. Open the oxygen needle valve fully.

NOTE: A back-fire might occur when turning on the oxygen if there is not enough acetylene being supplied. If this occurs, increase the acetylene supply by turning the acetylene pressure-adjusting screw farther to the right.

8. Adjust the acetylene pressure-adjusting screw to give a slight excess of acetylene to the flame.

9. Adjust the acetylene needle valve to give a neutral flame (see under Flame Regulation, page 25).

How to Shut Off the Blowpipe. In the case of the *injector type blowpipe*, first close the *acetylene* needle valve, and then the oxygen needle valve.

In the case of pressure blowpipes, first close the oxygen needle valve, and then the acetylene needle valve.

When laying aside the blowpipe for a short time, the pressure-adjusting screws on both regulators should be released by turning to the left until free.

When work is suspended for any considerable time, the valves on both cylinders should be closed.

Never light the blowpipe unless some oxygen is passing through it. If the blowpipe is lighted, or burned, with only acetylene passing through it, there will be a deposit of carbon made in the tip, which will in time clog the orifice and interfere with the perfect operation of the blowpipe.

Back-Firing. If the flame is not properly adjusted, or the tip becomes clogged, the blowpipe may back-fire. When this occurs, first close the acetylene needle valve quickly, then open it again fully and relight the blowpipe. If the back-fire continues, close both the acetylene and oxygen needle valves. Then relight the blowpipe and proceed in the usual manner.

If the blowpipe becomes overheated, it may back-fire. When this occurs, it may be cooled by plunging it into a bucket of water. Be sure that the acetylene has been shut off and a small quantity of oxygen is flowing through the blowpipe to prevent water backing into the tip and causing further back-firing when the blowpipe is relighted.

Oxy-Acetylene Blowpipe Flame

Character of Flame. The oxy-acetylene flame consists of two parts—an inner cone, which is incandescent; and an outer envelope, or nonluminous flame, which is sometimes called the secondary flame.

The temperature of the oxy-acetylene flame, taken at the extremity of the inner cone, is very much higher than that of all other flames. It is calculated to be approximately 6300° F. One of the main reasons for the superiority of the oxy-acetylene flame over all other welding lies in the fact that this high temperature is concentrated at the point of inner cone.

The character of the oxy-acetylene flame depends upon the proportion of oxygen and acetylene contained in the mixture and the thoroughness of the mixture as it issues from the tip of the blowpipe. Varying proportions of the gases produce three characteristic types of flame, Fig. 18, called, respectively, reducing, or carbonizing, flame; neutral, or welding, flame; and oxidizing flame. Each type has its characteristic appearance, and it takes only a little practice to instantly recognize each. The welder should at all times observe carefully the type of flame produced and promptly correct any divergence.

Neutral, or Welding, Flame. A neutral flame is produced when acetylene and oxygen burn in the proper proportion, theoretically 1.00 volume of oxygen to 1.00 volume of acetylene. The appearance of this flame is characteristic, Fig. 18 b. It is made up of a distinct and clearly defined incandescent cone, or jet, of bluish hue, surrounded by a faint secondary flame, or envelope, purplish yellow in color and of a bushy appearance.

The incandescent cone may be from $\frac{1}{16}$ to $\frac{3}{4}$ inch in length and is usually rounded or tapered at the end. The maximum temperature of the oxy-acetylene flame is $\frac{1}{16}$ to $\frac{3}{16}$ inch beyond the extremity of this cone.

Fig. 18. Oxy-Acetylene Flame. Top, Reducing Flame; Middle, Neutral Flame; Bottom, Oxidizing Flame

The middle illustration in Fig. 18 shows roughly the characteristic appearance and formation of the neutral, or welding, flame. This flame is the one most extensively used, and no welder is proficient until he is thoroughly familiar with its appearance and distinguishing characteristics and is able to maintain this flame under working conditions.

Flame Regulation. The neutral flame is obtained by starting with a flame having a slight excess of acetylene and gradually cutting down the acetylene supply by means of the blowpipe needle valve. As this is done, the streaky appearance of the inner cone will

gradually diminish. The flame is neutral when the streakiness *just* disappears.

Carbonizing, or Reducing, Flame. The reducing, or carbonizing, flame is produced when there is an excess of acetylene in the flame. This flame is of an abnormal volume, dirty yellow in color, of uniform consistency, and has a streaky appearance. By gradually decreasing the acetylene supply at the needle valve, the size of the flame is decreased, and gradually a white cone of great luminosity appears at the blowpipe tip. The extent of the reducing, or carbonizing, action of the flame is judged practically by the size and definition of the luminous cone. When this cone becomes more clearly defined and takes the form and color of a bluish white incandescent cone, or pencil, the streakiness is further diminished, and the flame approaches the neutral stage. The upper illustration in Fig. 18 shows a reducing, or carbonizing, flame that has a fair but not large excess of acetylene. The temperature of the reducing flame is considerably lower than that of the neutral flame.

Use of Reducing Flame. A slight excess of acetylene is used in the welding of brasses, bronzes, aluminum, and certain alloy steels to guard against the burning out of easily oxidized elements. It has also been used in the case of certain mild steels to increase the carbon content to secure greater hardness. In this connection it must be remembered that increase in hardness is usually accompanied by decrease in strength, so that in general welding an excess of acetylene should not be used.

Oxidizing Flame. An oxidizing flame is produced when there is an excess of oxygen in the flame. The effect of too much oxygen is to diminish the size of the flame, blunt or blurr the inner cone, and produce a weak, streaky, or scattering flame. In some blowpipes, the inner cone is not only diminished in size but is slightly bulged at its extremity as compared with the neutral flame, which is shown in the middle of Fig. 18. The lower illustration in Fig. 18 shows the oxidizing flame.

Caution Against Oxidizing Flame. An oxidizing flame should be carefully guarded against or it will become a source of trouble. An excess of oxygen will burn the metal, causing weak welds, and in the case of cast iron it will produce a hard weld that will be difficult to machine.

Manipulation of Blowpipe and Welding Rod

Position of Hose. Occasionally the hose is thrown over the operator's shoulder. In this case the weight of the blowpipe is suspended and held by the hose so that it is only necessary to impart the peculiar welding motion to the blowpipe, which can usually be done by the fingers. However, this method is not generally recommended, as it seriously hinders the free movement of the welding flame. It should be used only as a relief when the work is of long duration and the operator's wrist and forearm become tired.

Position of Blowpipe. The operator, having lighted the blowpipe and properly adjusted the flame, is now ready to begin welding. Grasp the blowpipe firmly in the hand, as shown in Fig. 19. The blowpipe is so designed that it balances properly when grasped at this point. It is not good practice to hold the blowpipe in the fingers, because it is not possible to manipulate the flame with as great regularity and control, nor will it be possible to do as heavy work without tiring.

Fig. 19. Correct Method of Holding Welding Blowpipe

Fig. 20. Blowpipe Should Not Be Inclined Too Much

Fig. 21. Blowpipe Should Not Be Held Too Vertical

Fig. 22. Blowpipe Should Not Travel Backwards

Inclination of Blowpipe. The head of the blowpipe should be inclined at an angle of about 60 degrees to the plane of the weld.

The inclination of the head should not be too great, Fig. 20, because the molten metal will be blown ahead of the welding zone and will adhere to the comparatively cold sides of the weld. On the other hand, the welding head should not be inclined too near the vertical, Fig. 21, or the secondary flame will not be utilized to its full value for pre-heating the metal ahead of the actual welding.

In ordinary welding practice it is best that the top of the blowpipe be so inclined and so directed that the maximum amount of preheating is obtained without blowing the molten metal ahead.

Travel of Blowpipe. The travel of the blowpipe should be away from the welder and not toward him, Fig. 22, as the work can be observed more closely and done more easily and quickly.

Movement of Blowpipe. In making a weld a simultaneous fusion of the edges of the parts to be joined and the welding rod is necessary. If this does not occur, a true weld is not produced.

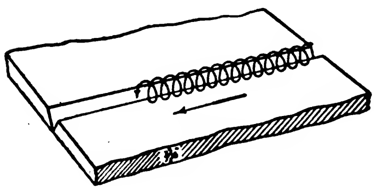


Fig. 23. Circular Motion of Blowpipe for Welding Light Sections

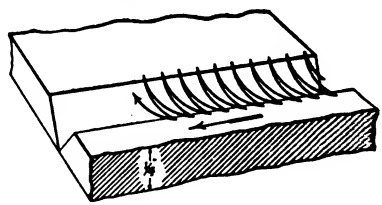


Fig. 24. Oscillating Motion of Blowpipe for Welding Heavy Sections

In the case of parts which have been chamfered out and which require the use of filling material, a peculiar motion must be imparted to the blowpipe, which will take in both edges of the weld and the welding rod at practically the same time.

In comparatively light work a motion is imparted to the blowpipe which will cause the incandescent cone to describe a series of overlapping circles, as shown in Fig. 23. This overlapping extends in the direction of the welding. This motion must be constant and regular in its advance so that the finished weld will have a good appearance. The speed of progress should be such that complete fusion of the three members referred to is secured. The width of this motion is dependent upon the size of the material being welded and varies accordingly with the nature of the work. It does not take much experience to establish the proper size motion and the proper rate of advance for the various sizes and kinds of metals.

In very heavy work, if the above system were used, a great deal of the motion would be superfluous. Consequently, a movement in which the cone of the flame will describe semi-circles should be used, as shown in Fig. 24. This confines the welding zone and concentrates the heat. While the progress is not so fast, it is more thorough than the other system for this class of work.

Importance of Movement. To the average beginner the regular control from these motions is difficult. It requires considerable practice and experience to become skilled in this, but it is the regularity of these motions that produces the characteristic rippled surface of good welding. The progress of a welder and the quality of his work can be determined to some extent by the skill with which he produces this effect.

Position of Welding Rod. After the beginner has mastered the peculiar motions of the blowpipe, his next step will be to properly introduce the welding rod into the weld in such a manner that the regular advance of the blowpipe will not be hindered or retarded.

Fig. 25. Correct Method of Holding Welding Rod

The welding rod, or wire, should be held and inclined, as shown in Fig. 25. In this position a sufficient quantity of material may be added at the right time. If the welding rod were held in a vertical or horizontal position, the welder would be liable to add an excess of metal, part of which would not be properly fused.

When to Add Welding Rod. Great care must be taken in adding this metal that the edges of the weld are in their proper state of fusion to receive it. If the metal is not hot enough, the added material will simply adhere to the sides, resulting in adhesion only, not a true weld. It is, therefore, necessary to produce equal fusion at the edges of the weld with that of the welding rod by the correct motion of the blowpipe.

How to Add Welding Rod. When the proper time arrives to add the filling material, the welding rod is lowered into the weld until it is in contact with the molten metal of the edges. When in this position the flame of the blowpipe is directed upon it, and thus fusion is produced.

In welds of unusual depth the end of the rod is immersed in the molten metal and the blowpipe flame is played around it. The material is thus protected from the air and the gases of the blowpipe. The heat of fusion in this case is supplied mostly from the molten metal which surrounds the rod.

Faults to Be Avoided. The usual faults of the average beginner are: first, failure to introduce the welding rod into the welding zone at the proper time; second, to hold the rod at the wrong angle; and third, to fuse either too little or too much of the rod. The filling material when melted should never be allowed to fall into the weld in drops, or globules, Fig. 26.

Fig. 26. Welding Rod Should Not Be Allowed to Fall into the Weld in Drops

Building Up the Weld. In welding it is customary to build up the welded portion in excess of the thickness of the original section. There are several reasons for doing this. First, the weld is reinforced and the strength is accordingly increased. Second, in case it is desired to finish the surface there is sufficient stock to allow machining. Third, in some cases small pin-holes or blowholes may be found just under the surface of a weld, which do not extend to any depth in the weld and may be removed by filing or machining.

GENERAL NOTES ON WELDING

The above are basic principles involved in producing all good oxy-acetylene welds. There are many detailed operations which must be learned by practice for the successful handling of the different metals, but by keeping in mind these basic principles and by applying them properly, the more difficult operations can be readily mastered.

Haste Fatal to Good Welding. It is a fundamental rule for successful welding that the operator must give his undivided attention to the work in hand. *Do not try to hurry over or slight any step of the work.* You cannot weld faster than the metal will melt and fuse together.

Burning a Hole in the Metal. Occasionally an operator becomes so interested in some minor detail of his work that he allows the flame to burn through the metal and form a hole.

How to Weld Up a Hole. It is a difficult operation for a beginner to fill these holes. His first attempts usually result in enlarging the holes instead of closing them. The proper way to take care of this is to incline the blowpipe so that the flame is almost parallel to the surface of the work, Fig. 27. With the blowpipe in this position, play the flame upon the upper edge of the hole until the sides become plastic, taking care that the edges do not become entirely fused. When the edge is in the proper condition, the welding rod is interposed and a small amount of metal is added to the top edge of the hole. This operation is repeated until the hole is filled in. As the work progresses, the blowpipe is gradually raised until it resumes its normal position.

Fig. 27. Method of Filling in a Deep Hole—Start at the Upper Edge

Overhead and Vertical Welding. In welding overhead, Fig. 28, or vertically, Fig. 29, the same procedure is followed as in filling a hole. The metal should not be allowed to reach the state of fusion that is secured in ordinary welding. It should be hot enough to assimilate the welding rod, but not so fluid that it will flow out of the weld. In overhead welding care should be taken that oxidation does not occur, because the molten oxide will flow from the weld and seriously inconvenience the operator.

Fig. 28. Overhead Welding

Beginning a Long Weld. In beginning a long weld pains should be taken to see that it is started properly, and at this point of the

work time should not be spared. When the weld is properly started the speed may be increased. As the weld advances the speed becomes

Fig. 29. Vertical Welding

greater, because the material becomes heated up and the blowpipe action is faster.

Defects in Welds. There are a number of sources of defects in welds, and the average bėginner usually encounters all of them before he becomes a skilled welder.

Improper Flame Adjustment. If the flame is not properly adjusted the weld will be inferior. The commonest fault is the presence of too much oxygen in the welding flame. Unless the operator takes a great deal of care in removing the oxidized particles, they will be incorporated in the weld, Fig. 30. The oxide, of course,

Fig. 30. Oxidised Weld

Fig. 31. Failure to Completely Penetrate to the Bottom of the Weld

greatly decreases the strength and greatly affects the other mechanical properties of the weld.

Failure to Penetrate. A fault, not only of the beginner but also of the skilled operator, is failure to penetrate to the bottom of the weld, Fig. 31, and is the cause of a great many defective welds. In his desire to complete a weld as soon as possible, the operator very often hastens over the most important part of the work, which is to secure the absolute fusion of the edges at the bottom of the weld. Failure to do this not only reduces the section of the metal at the weld, but also gives a line of weakness in case the welded pieces are submitted to bending or transverse strains.

the weld

Adhesion of Added Metal. When molten metal from the welding rod is added to the edges of the weld which are not in fusion, a weld is not secured. The added metal merely adheres to the cooler metal, Fig. 32, and perfect fusion is not secured. Adhesion may be caused by improperly chamfering the pieces to be welded, by improper inclination of the blowpipe, by improper use of the welding rod, or by faulty regulation and manipulation of the welding flame.

The tendency of beginners is to not prepare the pieces properly for welding. Usually the chamfering, or grooving, is either not deep enough, that is, does not extend entirely through the section to be welded, or it is not wide enough. In welding pieces improperly prepared the tendency of adhesion is great.

The most common fault is the addition of the welding rod to the edges of the weld before they are in fusion. The adhesion in this case is applied to both edges. Sometimes one edge of the weld is in fusion. but the other is not. In this case adhesion is applied to only one side,

Fig. 33. Weld *Not* Properly Reinforced

Fig. 34. Weld Properly Reinforced

but with the effect that the strength of the weld is lessened the same as when adhesion occurs on both sides.

In some cases the edges of the metal are brought to a state of fusion too soon, so that oxide has an opportunity to form on the edges

of the weld. Then, when the welding rod is added, adhesion occurs with a film of oxide separating the edges and the added material.

Often an operator will concentrate the flame upon the welding rod and the edges of the weld. Then, as the blowpipe is played around the welding rod, some of the molten metal is forced ahead. The metal ahead is not in the proper state of fusion and consequently adhesion results.

Insufficient Reinforcing. It is not uncommon to see welds produced that do not contain enough metal, Fig. 33. All welds should be reinforced with additional metal as in Fig. 34. In case a smooth finish is desired this excess metal can be removed by grinding or machining. Too great an excess of metal must not be added because this takes extra time and the gases are wasted.

WELDING FOR DIFFERENT METALS

PROPERTIES OF METALS

Before the beginner takes up the actual welding of metals, it is necessary that he study their properties, peculiarities, and behavior under the action of the welding flame. Some of the physical properties of the more common metals are given in Table I.

Melting Point. The first property that the welder should consider is the melting point or temperature at which the metal will fuse or become fluid. The average welder is usually fairly familiar with the difference in melting points of lead or zinc, and iron or steel; but he is usually not familiar with the difference between the melting points of brass, bronze, copper, white cast iron, gray cast iron, etc. This knowledge is especially important if it becomes necessary to weld members of dissimilar materials.

Thermal Conductivity. The conductivity of a metal is its ability to transmit heat throughout its mass. This property, which is not the same for all metals and varies within wide limits, is of great importance to the welder. It can be seen that if one metal conducts or transmits the heat from the welding blowpipe more rapidly throughout its mass than another, it is necessary that allowance be made both as to the pre-heating equipment and the size of the blowpipe used.

In welding metals of high thermal conductivity, it is necessary to use oversize blowpipes—as in the case of copper. Although the

TABLE I
Properties of Metals

METAL	Weight Lb. per Cu. In.	Tensile Strength Lb. per Sq. In.	Melting Point Deg.	Relative Thermal Conductivity Copper = 1.00	Specific Heat	Coefficient of Linear Expansion	Approximate Expansion from 60° to Melting Point In. per Ft.
ALUMINUM							
Cast	0.093	15,000	1210	0.524	0.22	0.0000123	$\frac{11}{64}$
Drawn	0.098	24,000 to 40,000				0.0000136	$\frac{12}{64}$
BRASS							
Cast, Red	0.3103	20,000	1740	0.251	0.09	0.00000957	$\frac{12}{64}$
Cast, Yellow	0.2959	18,000		0.208			
Drawn		40,000 to 78,000				0.00001052	$\frac{14}{64}$
BRONZE							
Manganese		75,000 to 90,000	1692	0.735			
Phosphor	0.32	50,000					
Tobin	0.3195	60,000 to 100,000				0.00000986	$\frac{12}{64}$
COPPER							
Cast		22,000	1980	1.00	0.095		
Drawn	0.3195	31,000				0.0000094	$\frac{14}{64}$
IRON							
Grey cast	0.2604	20,000	2190	0.124		0.00000556	$\frac{9}{64}$
White cast		18,000	2000				
Wrought	0.2779	55,000	2730	0.157	0.11	0.00000648	$\frac{13}{64}$
LEAD	0.411	1,780	620	0.091	0.03	0.0000155	$\frac{7}{64}$
NICKEL	0.312	76,000	2650	0.155	0.11	0.000007	$\frac{14}{64}$
STEEL							
Mild	0.283	50,000 to 75,000	2690	0.118	0.117	0.0000063	$\frac{13}{64}$
Hard		65,000 to 80,000	2570		0.1175		
ZINC	0.2526	5,500	785	0.29	0.09	0.0000144	$\frac{8}{64}$

melting point of copper is low, yet the conductivity is high, and consequently, a blowpipe of the same size as would be used on a smaller section of steel must be used.

The conductivity of a metal will have a great bearing on the consideration of expansion and contraction. If one metal absorbs or leads the heat away from the welding blowpipe more rapidly than another, the heated area will become very much larger, and, consequently, the expansion and contraction more severe.

Specific Heat. The specific heat of a metal is the amount of heat that is absorbed when it is raised through a certain range of temperature. A metal having a low melting point but relatively high specific heat may require as much heat to bring it to its point of fusion as a metal of high melting point and low specific heat— as in the case of aluminum compared to steel.

Coefficient of Expansion. The linear increase per unit length when the temperature of a body is raised through one degree is its coefficient of expansion.

The coefficient of expansion varies materially with the different metals. Of the metals most commonly welded, as seen from Table I, aluminum has the greatest expansion, bronze and brass next, then copper, steel, and iron. Aluminum expands almost twice as much as iron or steel, consequently, in dealing with aluminum work it is necessary that this feature be considered very seriously.

Expansion and Contraction. When a body of any material is subjected to an increase in temperature, it expands and its volume and linear dimensions are increased. When the temperature is lowered a reverse action takes place, the body contracts, and its volume and linear dimensions decrease. Metals or metallic bodies are very susceptible to this change in volume due to variations in temperature.

The effect of this expansion and contraction is of great importance to the welder. It is impossible for the welder to produce satisfactory work until he has a knowledge of the nature and the amount of expansion usually encountered and of how to compensate for it.

The expansion and contraction of the welded piece cannot be controlled or arrested mechanically, because the force of expansion is irresistible. In malleable, or ductile, metals the expansion is liable to produce warping or deformation of the piece, while in materials

that are not of this nature—brittle materials—such as cast-iron, the result of the expansion and contraction, unless properly taken care of, is fracture.

If the expansion can take place in all directions, it will give the welder no trouble, as the piece will expand equally all over, and upon cooling will contract to its original volume. If, however, the welding takes place at a point that is confined by various parts or by the particular construction of the piece, it is then necessary to give it due consideration.

The resultant effect of contraction, produced by the cooling of the welded object, must be considered equally with that of expansion. Contraction produces as much cracking, or checking, and warping as does expansion. Therefore, it is essential that the welder study not only the effect of expansion, but also the subsequent result produced by contraction.

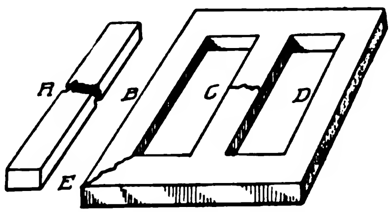


Fig. 35. Simple Case of Expansion and Contraction

Methods of Handling Expansion and Contraction. There are many ways of taking care of expansion and contraction, such as heating the entire piece to a dull red heat, simultaneously heating opposing similar parts, and breaking the piece at certain points to allow free expansion and then re-welding at the break. If the material is ductile or malleable, it may be warped or bent out of shape to such an extent that the spring will take up completely the opposing force of expansion and contraction. This, however, entails an accurate calculation and should not be used except where no other means are feasible.

Handling Simple Case of Expansion and Contraction. We will first consider the simplest condition of welding. Assume that a long bar which is free at each end has broken at point A, Fig. 35. In this case the welding may be carried out without any fear of encountering difficulties due to expansion and contraction. The bar is free to expand and contract at each end. While there might be some warping or deformation due to the heat of welding if the blowpipe is not handled properly, yet, there is very little danger of weakening the weld because of internal strains.

Now let us assume that this bar is part of a casting, as shown at *C*, which is surrounded and joined to a rigid frame *B* and *D*. In this case the expansion and contraction due to welding must be taken care of. It is readily seen that the expansion is not the force that will cause trouble, because when the two pieces expand during welding, the metal, which is in a fused condition, is so soft that the expansion will take place in the weld and the edges will approach each other. This will not affect the confined frame. However, consider the action on the metal when it starts to cool. Contraction sets in and, as it is irresistible, there must be some compensation for the shortening of the bar *C*. If the material is ductile and one that will stand bending, deformation or warping will occur. But, if it is of low ductility, such as cast iron, a break will occur either at the weld or at a line of less resistance.

Methods of Handling. In welding an article of the general nature, shown in Fig. 35, when the break is in an internal member, such as at *C*, there are several ways of handling it.

Heating Entire Casting. The entire piece can be raised to a high temperature as referred to above and in this way produce an expansion in the entire mass, and, consequently, equal contraction. However, this is not necessary, and in some cases is not possible; the operation also takes more time and costs more. It is only necessary at the time of welding to heat simultaneously similar parts to a good red heat, in order that the stiffness of the frame may be lessened, and thus take care of the contraction.

Heating Confining Members. In the example referred to, the application of a pre-heating burner at the points *B* and *D* will cause the frame to expand in the linear direction of the expansion and contraction produced by the weld. Therefore, when the weld is finished and the frame starts to cool and contract, the parts *B* and *C*, in as much as they were raised to practically the same temperature as the metal surrounding the weld, will contract equally and, therefore, a successful weld will be produced.

Use of Wedges. If it is impossible to apply pre-heating at the points referred to, another method may be used. By the use of jacks, wedges, or similar devices, the casting may be sprung or bent out of shape, as shown by the dotted line, and the edges of the part to be welded may be separated. After the weld is executed and con-

traction sets in, the jacks, wedges, etc., may be withdrawn. The return of the sprung parts to their original positions will compensate the contracting strains.

Breaking Another Member. Another method of taking care of expansion and contraction is that of breaking the piece at some extraneous point, such as at *E*. In this case the expansion and contraction will be free to act at the point *C* without any fear of serious after-effect, as the casting is free to spring in any direction, because of the loose joint at *E*. As the point *E* is not confined, it is an easy matter

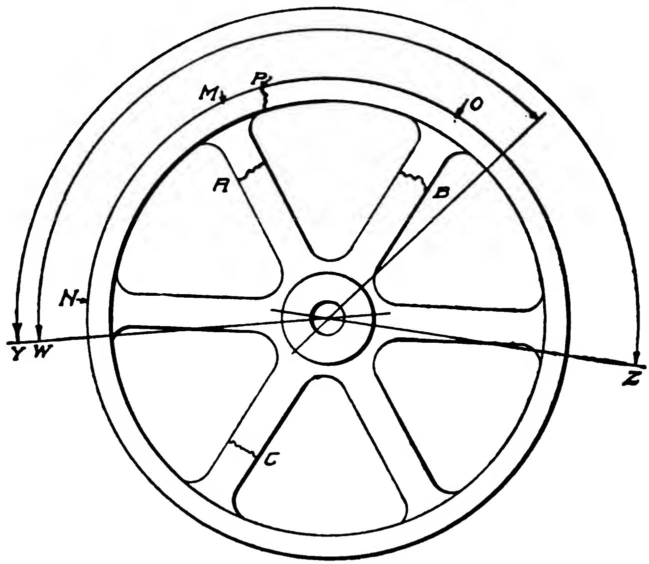


Fig. 36. Complex Case of Expansion and Contraction

to reweld this break without fear of any bad results. This method, however, is dependent upon the thickness of the metal and is one that should not be attempted unless no other means are feasible.

While this diagram is extremely simple, nevertheless the principles to be considered and the methods of handling them are indentical with those experienced in all practical work. A clear conception of the forces acting, the nature of their action, and how to counteract them, is essential in work with the oxy-acetylene blowpipe.

Handling Complex Case of Expansion and Contraction. A good example of a complex case of expansion and contraction is the flywheel or pulley with broken spokes, as shown in Fig. 36.

Assume that the spoke is broken at *A*. If this were welded without considering and allowing for expansion and contraction, the shrinkage strain would be so great that failure would occur.

Pre-heating the rim from *W* to *X* to a dull red heat will cause the rim to expand outwardly, separating the edges of the broken spoke. While in this state the weld should be made rapidly and then the entire wheel allowed to cool slowly. Thus a good weld without the presence of internal strains will be produced. The expansion of the rim, due to the pre-heating, will offset the contraction of the weld in the spoke.

If the crack in the spoke is near the rim, it is only necessary to apply a gas or oil burner to the rim at *M* until it is at a red heat. This will expand the spoke and rim, and separate the edges of the break sufficiently to offset the contraction of the weld.

The spoke may be welded at *A* without pre-heating if the confining member—in this case the rim—is broken to lessen the rigidity. In order to do this the rim must be broken at a point *P*, always close to the spoke. First one side of the spoke is strongly tacked at the weld. Then the other side is welded two-thirds the way through. The tack is then melted out and the weld completed. The rim is then welded at point *P*. If the edges do not meet accurately, they may be brought to do so by heating either at *M* or *O*, according to which edge is low.

If two spokes are broken as at *A* and *B*, the same general procedure as given above may be followed. In case it is necessary to pre-heat a large portion of the casting it is important that the pre-heated area always extend beyond the spokes adjacent to those fractured, from *Y* to *Z*.

If two diametrically opposite spokes are broken such as *B* and *C*, each may be treated as independent of the other and welded by any of the methods given above.

PRE-HEATING

Reasons for Pre-Heating. Pre-heating is employed for three fundamental reasons:

To Compensate for Expansion and Contraction. When pre-heating is used to counteract the effects of expansion and contraction, it is necessary that the casting be heated either in certain confined

localities or entirely to a dull red, or in some cases to a bright red heat. With this treatment the internal strains existing in all welds are reduced to a minimum.

To Decrease Cost of Welding. When a weld is being executed on a large casting, it is too expensive to supply the total amount of heat required from the blowpipe alone. To offset this, pre-heating by some cheaper method is used, and the result is usually a saving of from 25 to 60 per cent of the cost of welding by means of the blowpipe alone. Then, too, it is possible to accomplish the welding with greater speed, due to the casting being at a higher temperature.

To Make Metal More Receptive to Action of Welding Flame. When the temperature of a metallic body is raised, the state of the metal surrounding the weld is more nearly that of the molten metal in the weld, and the result is a more homogeneous and smoother-grained fusion, dependent upon the temperature reached in pre-heating.

Fig. 37. Pre-Heating with Welding Blowpipe

Fig. 38. Gas Burner for Pre-Heating

Methods of Pre-Heating. There are various means of carrying out this preliminary heating. The method used should be governed by the particular work in hand.

Pre-Heating with Welding Blowpipe. The simplest method and the one most used on light objects is that of utilizing the flame of the welding blowpipe, Fig. 37. In welding thin castings, it is only necessary that the flame of the blowpipe be played upon the parts at the line of the weld for a few moments, in order that the pieces may obtain a red heat. This is, however, expensive, and should only be employed on small objects.

Gas and Oil Burners. If the article to be welded is of fairly large size, the use of gas, Fig. 38, or oil burners, Fig. 39, is economical.

Fig. 39. Oil Burner for Pre-Heating
Courtesy of Oxweld Acetylene Company, Chicago, Illinois

Fig. 40. Charcoal Fire for Pre-Heating Castings

These pre-heating torches, however, limit the area of the surface covered, so consequently are used more successfully on that work

which requires localized pre-heating. The flames produced are of sufficient temperature, but not the necessary volume to evenly heat the entire casting.

Charcoal Fire. The most satisfactory method of pre-heating is by means of a charcoal fire built around the article to be welded. The usual procedure is to build a small temporary fire-brick furnace around the piece and fill in with charcoal, Fig. 40. This is ignited by means of kerosene. As the progress of the ignition of the charcoal is rather slow, the pre-heating is carried out gradually. The nature of this pre-heating flame is of such evenness and volume that the temperature imparted to the casting is the same throughout its mass.

In welding large castings of a complicated nature, such as engine cylinders, it is necessary that they be pre-heated evenly throughout and that the welding be carried on while the casting is at a dull red heat. Therefore, the most satisfactory means of accomplishing this is by embedding the casting in charcoal and carrying on the work while it is embedded in the hot coals.

STEEL WELDING

General Considerations. The welding of steel is apparently simple, but in reality it is a fairly difficult material to weld and should receive the welder's best thought and care. It is simple to produce a nice looking weld that has a smooth even surface, but it is not easy to produce a weld that is strong and will stand up under service. Welds of high strength are absolutely necessary in cases like automobile frame and crankshaft repairs, because a poor weak weld might prove fatal.

Oxidation. It is practically impossible to prevent a certain amount of oxidation; but it is very important that it be kept to a minimum. The oxide that forms on the top of the weld may be removed quite easily, because it melts at a lower temperature than the metal. It may be floated off the weld while hot, or removed as a thin skin after the weld becomes cold. Care must be taken, when adding the welding rod, Fig. 30, page 32, that this film of oxide is penetrated, because if this is not done the oxide will be incorporated in the weld, which will therefore be very weak.

Expansion and Contraction. The effect of expansion and contraction is not as severe in steel welding as in cast iron or aluminum;

but, nevertheless, it must receive due consideration. In steel castings it is taken care of in a manner similar to that used for cast iron, that is, by pre-heating. In sheet-steel work the creeping, or drawing, of the edges is taken care of by arranging the edges of the sheets at an angle, or by tacking, or by the use of jigs to hold the work.

Welding Rod. Each welding head is designed for use with a certain thickness of metal. As the volume of the flame varies with the size of the welding head, care must be used to select a welding rod of the correct size in making welds in sheets of various thickness. There is great danger of burning a welding rod that is too small, or, if the rod is too large, it may not melt through and will enter into the weld in a semifused condition and not be thoroughly incorporated in the weld. The following table shows the proper size of welding rod to be used for the different thicknesses of sheets:

Thickness of Sheet	Size of Welding Rod
Up to $\frac{1}{8}$ inch	$\frac{1}{16}$ inch
$\frac{1}{8}$ to $\frac{3}{16}$ inch	$\frac{1}{8}$ inch
$\frac{1}{4}$ to $\frac{3}{8}$ inch	$\frac{3}{16}$ inch
$\frac{1}{2}$ and over	$\frac{1}{4}$ inch

Never use twisted wire made up of two or more strands, because this offers a very large surface for oxidation, which is a condition operators must try to avoid.

Neutral Flame. The importance of maintaining a neutral flame at all times cannot be emphasized too strongly. An excess of acetylene in the flame tends to carbonize the work, resulting in a hard brittle weld; while an excess of oxygen will oxidize or burn the metal. It is seldom necessary to adjust the flow of gases through the blowpipe after correct adjustment has once been made, except in the case of very heavy welding where the intense heat of the molten metal tends to expand the orifice in the tip of the welding head. This has some effect on the size and shape of the flame and necessitates more or less frequent adjustment to keep the gases in correct proportion to maintain the neutral flame.

Movement of Blowpipe and Addition of Welding Rod. In welding sheet steel, it is necessary that the oscillating movement previously referred to be imparted to the blowpipe and used continuously—both because of its high-melting point and the behavior of the molten metal under the action of the blowpipe flame. Steel cannot be pud-

dled and it is therefore necessary to add the filling material in thin overlapping layers. The importance of securing a perfect bond between every two layers can be readily seen. To make a true weld, a simultaneous fusion of the edges of the sheets and the welding rod must be produced.

To do this with light- and medium-weight sheets, a motion is imparted to the blowpipe which will cause the flame to describe a series of overlapping circles as previously described, page 28. This overlapping extends in the direction of the welding and, in order to make a weld of good appearance, must be constant and regular in its advance.

In heavier plates, while the same rule governing simultaneous fusing of the edges of the sheets and welding rod apply, the filling of the groove is accomplished in a slightly different manner. On account of the depth of the weld the flame is not large enough to fuse a body of metal of so great an area, and it is impossible to fill the groove entirely from bottom to top with one layer of metal. The bottom edges of the groove must first be thoroughly fused for an inch or two before adding metal. When this is done, bring the flame back to the starting point and when the metal is in the proper molten condition add the filling material, oscillating the blowpipe in a series of semicircles, as previously recommended for welding heavy sections, page 29. Follow this method of filling the groove in sectional layers until the proper height is reached, making sure that thorough fusion is accomplished between the layers themselves and the edges of the sheet and the layers of filling material.

After-Treatment. Correct after-treatment is as essential for successful welding of steel as the actual welding operation. Proper after-treatment will inprove the grain of the metal and will materially increase the strength and toughness of the weld. There are three principal treatments that will benefit the material and are easily employed in the repair shop. These are called annealing, hammering, and quenching.

Annealing. Annealing consists of reheating the work to the proper temperature and then allowing it to cool slowly. The work should be heated to a bright cherry red by means of a blowpipe or suitable burner, or in a furnace that can be carefully regulated. Care must be taken that the work reaches the bright cherry red, because

heating to a lower temperature will be detrimental and may leave the weld weaker than if not annealed at all. After the work has been heated, it should be allowed to cool very slowly and evenly. It should be covered over with asbestos or dry sand, packed in lime, or left to cool in the furnace. Care must be taken that cold air currents do not strike the work before it has become cold.

Hammering. Hammering consists of reheating the weld to the proper temperature and then hammering while at this temperature with a hand hammer. The weld should be heated to a bright yellow heat and then hammered with quick light blows. Heavy hammers or heavy blows should never be used. The hammering should cease as soon as the weld falls to a dull red, for otherwise the fine grain of the metal will be spoiled and the weld will be weak.

Quenching. Quenching consists of reheating the work to the proper temperature and then plunging it into water, brine, or oil. This method is used mainly for small articles. It is used quite often for hardening and tempering. Quenching should be employed only in special cases, because, although it will make the work strong, it will also make it hard and brittle.

Light Sheet-Steel Welding

Preparation. In welding two short pieces of flat steel, up to $\frac{3}{16}$ inch in thickness, no special preparation of the plates is necessary, except to have them flat as possible and to be sure that the edges are reasonably true. The two pieces of metal should be placed on a level surface, preferably fire brick or some other nonconductor of heat.

Expansion and Contraction. With light sheet, expansion and contraction are cared for by tacking the seam at certain intervals or by arranging the sheets so that the edges to be welded are set at a slight angle rather than parallel, Fig. 41. The correct amount of divergence is determined by the thickness of the metal and should be from $2\frac{1}{2}$ to 6 per cent of the

Fig. 41. Light Sheets in Position for Welding

length of the weld. The amount of divergence between these limits varies also with the speed of welding, fast welding requiring less spread. After the plates are in this position, place two pieces of flat bar steel on each side, about $\frac{1}{2}$ inch from, and parallel to, the line of the weld. Clamp or weight these pieces down so that they cannot be readily moved. The work is now in position for welding.

Jigs. In making this type of weld in flat sheet steel in longer lengths, up to several feet and up to $\frac{3}{16}$ inch in thickness, a welding jig made up with two slotted jaws hinged at one end and provided with hold-down clamps at the other end will be found more convenient than the individual hold-down bars.

Fig. 42. Jig for Holding Light Sheet Cylinders for Welding

For welding short cylinders, a jig made similar to that shown in Fig. 42 will be found satisfactory.

Tacking. Tacks, or short welds, at intervals of from 2 to 6 inches, according to the thickness of the sheet, can be made the entire length of the seam to hold the edges in position for welding if jigs are not available.

One of the above methods must be used to take care of the creeping action owing to expansion when the flame of the blowpipe is applied to the metal. If this action is not provided against and the two sheets are placed with parallel edges, they will first diverge

when the welding is started, as in *a*, Fig. 43, and then gradually come together. When about half of the weld has been made, they will again become parallel as in *b*. From this point on as the welding continues the sheets will draw together until they overlap, as shown in *c*.

(*a*) (*b*) (*c*)

Fig. 43. Result of Not Providing for Expansion

Welding Light Sheet. Select the welding head and a piece of iron welding rod of the size suitable for the thickness of the sheet and place the work in position for welding.

As steel is very sensitive to the action of the carbonizing flame and particularly to that of the oxidizing flame, a constant, nonvarying, neutral flame should be maintained. The incandescent jet should be of maximum size and clear outline at all times.

With the correct neutral flame, start welding at the point where the two sheets meet. Impart the circular motion to the blowpipe, described under Movement of Blowpipe, page 28, to produce the correct rippled surface on the finished weld. When the

Fig. 44. Appearance of Good Weld in Light Sheet Steel

Fig. 45. Appearance of Poor Weld in Light Sheet Steel

weld is finished, turn out the blowpipe and allow the work to cool until the metal is black.

Then remove the hold-down bars and examine the weld. If you have followed instructions, your weld will have the appearance shown in Fig. 44 and will not be like that shown in Fig. 45. On

closer examination you will find that all the particles of dirt and impurities you noticed floating on the top of the molten metal when you were welding are now lying with the oxide on top and alongside of the weld where they can be readily brushed or scraped off. Now take your job to the shears and cut off one or two pieces. Upon examination, the cross-section should present the same uniform texture and color in both the weld and the sheet.


Fig. 46. Lap Welds Should Never Be Used

Types of Welds in Light Sheet. *Lap Weld.* Lap joints, either single or double, Fig. 46, *should never be used* in welding sheets of any thickness because the weld will be subjected to a shearing strain. Welds when completed should be under tension or compression strains, never under shear or bending strains.


Fig. 47. Butt Weld in Light Sheet

Butt Weld. The most common and the simplest weld to prepare in light sheet is the butt joint, shown in Fig. 47.


Fig. 48. Flange Weld in Light Sheet

Flange Weld. Another type of weld in light sheet, but one that entails some preparation, is made by flanging up the welding edges about $\frac{1}{32}$ to $\frac{1}{16}$ inch, Fig. 48, laying the two pieces flat and parallel on the welding table and executing a flange, or edge, weld. It is not necessary to use welding wire with this type of weld, because the metal in the flanges when they are fused together acts as a filling agent. By careful manipulation the edges can be fused down to a small bead, practically flush with the surface of the sheet.

Cylinders. In welding light sheets that have been rolled in cylindrical form, the separation of the edges can be accomplished by placing a wedge about two-thirds of the way down the length of the seam after the welding is started, Fig. 49. As the welding progresses the wedge should be moved further along the seam and withdrawn entirely as the work nears completion.

Fig. 49. Method of Welding Light Sheet Cylinders—Using Wedge to Space the Edges

Tacking can also be resorted to in welding cylindrical forms, although this results in the deformation of the cylinder, as shown in Fig. 50, and makes it necessary to hammer or re-roll the cylinder into shape.

Fig. 50. Result of Tacking a Light Sheet Cylinder—The Weld Draws up Pointed

The edges of very light sheet cylinders can be flanged and an edge, or flange weld, executed; but this method cannot be recommended with sheets heavier than $\frac{1}{16}$ inch.

Corner Welds. In making a corner weld in the lighter gage sheets up to $\frac{1}{16}$ inch, the edges of the sheet should be flanged, as shown in Fig. 51. In sheets from $\frac{1}{16}$ to $\frac{3}{16}$ inches in thickness, it is only necessary that the edges of the sheets run as true as possible in position, as shown in Fig. 52. Tacking is necessary in this case, as the sheets, due to expansion,

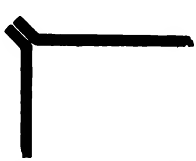


Fig. 51. Corner Weld for Very Light Sheets, up to $\frac{1}{16}$ Inch Thick

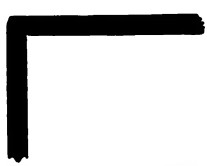


Fig. 52. Corner Weld for Light Sheets, $\frac{1}{16}$ to $\frac{3}{16}$ Inch Thick

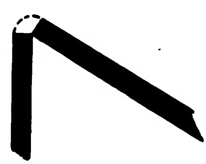


Fig. 53. Sharp Corner Weld for Light Sheets

readily move out of position when welding is commenced. On welds of this latter type it is necessary to use welding wire.

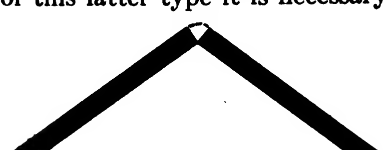


Fig. 54. Broad Corner Weld for Light Sheets

Two other forms of corner welds are illustrated in Figs. 53 and 54. These sheets should be tacked and, if $\frac{1}{16}$ inch or thicker, welding wire should be used.

Tank Heads. In making tanks when either a bottom or heads in both ends are required, the method of putting in the heads is governed by the design and purpose for which the tank is intended.

Storage Tanks. If the tank is to be used as a storage receptacle, such as gasoline tanks, the heads can be cut to the outside diameter of the shell, laid flat on the end of the shell and tacked at intervals all the way around, Fig. 55. Then the shell, with the heads securely tacked in place, is laid on its side and the welding is started at any point, the tank being turned, from time to time, as the welding progresses. Or, the heads can be flanged to any depth desired, and backed into the shell until the edge of the flange and the edge of the shell are even, Fig. 56, making sure that the head fits the shell snugly. They are then tacked and welded in an upright position. This latter method is the better of the two from the welding standpoint.

Pressure Tanks. When a tank is built to stand a considerable pressure, such as air-compressor tanks, the heads should always be dished and flanged, the boiler-maker's standard specifications govern

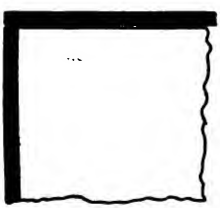


Fig. 55. Head Weld for Storage Tanks

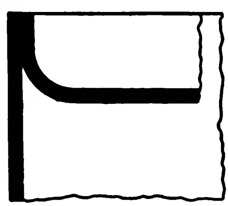


Fig. 56. Head Weld for Storage and Medium-Pressure Tanks

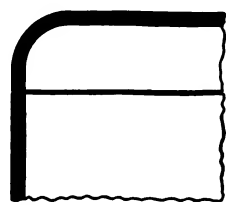


Fig. 57. Head Weld for Pressure Tanks

this. The heads can be either backed in and an edge weld made, Fig. 56, or set up so that the edges of the flange exactly meet the edges of the shell, Fig. 57. In either case the parts should be tacked together before welding. In the second case, care should be used in flanging to have the outside diameter of the flange exactly the same as the outside diameter of the shell. This method is the best because the weld is under direct tension or straight pull.

Tubes. Light-weight tubing should be squared off and fitted nicely before welding is attempted. It should be tacked in several places and then welded.

Heavy Sheet-Steel Welding

Preparation. In welding heavy sheet metal above $\frac{3}{16}$ inch in thickness, a certain amount of preparation is necessary. The success of the weld depends in a great measure upon the proper

preparation of the work to be welded. While the preparation is governed largely by the particular location of the weld and form of the sheets to be welded, there are certain general rules that must always be observed.

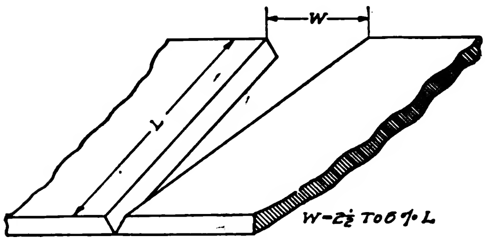


Fig. 58. Heavy Sheets in Position for Welding

In making a perfect weld it is necessary that the metal at the weld be completely fused throughout its entire thickness. In light sheets the projection of the flame is great enough to produce this result, but heavy sheets would require a flame of such magnitude that it could not be readily handled. Therefore, in order to facilitate complete fusion, the edges of the sheets to be welded are

Fig. 59. Welding Heavy Plate Steel Cylinder
Note grooving of edges, spacing clamps and wedge about half way along the seam

chamfered or beveled to form a V-groove, the width of this V being equivalent, or nearly so, to the thickness of the metal.

Expansion and Contraction. With heavy sheet, expansion and contraction are cared for by observing the same rules of spacing, Fig. 58, and clamping, Fig. 59, or, in some cases, tacking, in order to hold the work in position for welding, as described for light sheets on page 47.

Welding Heavy Sheet. Select a welding head and a piece of iron welding rod of the proper size to accomplish the work in hand.

Because steel is sensitive to the carbonizing and oxidizing flames, it is necessary to maintain the correct oxygen pressure and a neutral flame at all times. In ordinary heavy sheet welding there are two general methods of procedure, either of which will produce a good weld when properly executed. These methods may be called welding by sections, and continuous welding.

Welding by Sections. Welding is started by first playing the flame of the blowpipe along the edges of the pieces to be welded. This is done merely as a preliminary heat treatment. The flame is then played on the bottom of the groove at the beginning of the weld until the edges are in a molten condition, at which time the blowpipe is momentarily withdrawn and the molten metal allowed to flow together. This is done without the aid of any filling material. Care must be exercised at this point, because successful welding depends upon complete penetration and perfect union of the bottom edges. When a perfect union of the two members is secured for about one or two inches, the welding rod is brought into use. By playing the flame around the welding rod in contact with the edges of the weld instead of directly on the welding rod, it is possible to bring them both to the point of fusion simultaneously. The rod is then gradually added to the weld, layer by layer, until this particular section of the weld is built up to the required height. The flame is then played on the face of the metal just added and on the bottom of the groove until fusion of these parts is secured. The welder then repeats the operation described above until the next small section of the groove is filled up to the proper level. The welding progresses by means of these small sections, each being built up completely before another is started.

While the metal is in a fused condition, the velocity of the flame will cause the molten metal to become slightly indented. The flame should be withdrawn momentarily, from time to time, thus

allowing the fluid metal to flow back to its normal level, in which position it will solidify. Skill in steel welding depends greatly on this manipulation, as the flowing together of the different molten centers produces the weld.

Continuous Welding. In this method the weld advances continuously with each addition of metal. By this method the metal is added in short layers, sloping rather than horizontal. The weld is started by fusing together the bottom edges of the groove as previously described. The filling material is then added so that it will be from ⅛ to ¼ inch high at the starting point and slope to nothing in a length of 1 or 1½ inches along the bottom of the groove. This will give an inclined surface to which the filling material is added in parallel layers. The added metal being on a sloping plane, the fusion of the bottom edges is always carried ahead with the welding, as each layer includes a small section of the bottom of the groove.

Types of Welds in Heavy Sheet. *Lap Weld.* As explained on page 48, the lap weld *should never be used.*

Butt Weld. The beveled or grooved butt joint is the only welded joint that should be employed on heavy sheets, Fig. 60. The most satisfactory method of handling the work is to space the edges, because tacking is very likely to not hold on heavy sheets.

Fig. 60. Butt Weld in Heavy Sheet

Never weld sheets from both sides, because unequal strains are likely to be introduced by localized heating when working on the second side.

Cylinders. Heavy cylinders should also be prepared for the grooved butt weld, for the same reasons as for heavy sheets.

Fig. 61. Corner Welds for Heavy Sheets

Corner Welds. The two most satisfactory corner welds for heavy sheet are shown in Fig. 61. Although the second is a little

more costly to prepare, it is more satisfactory than the first because it insures better penetration.

Tank Heads. In welding bottoms or heads in tanks of heavy sheet, the purpose for which the tank is to be used governs the method of constructing the heads as it does in welding tanks of lighter gage. The same general rules apply in both cases, the main difference being

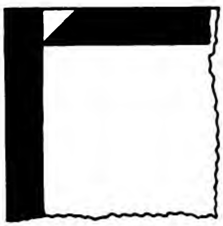


Fig. 62. Head Weld for Storage Tanks

Fig. 63. Head Weld for Medium-Pressure Tanks

Fig. 64. Head Weld for High-Pressure Tanks

that the edges of the heavy shells and heads are chamfered, dependent on the design of the tank. All require tacking to hold the members in position for welding.

Storage Tanks. In the case of putting on a flat head, the edge of the head only is chamfered, Fig. 62, while in putting in a flanged head where an edge weld is to be executed, as in Fig. 63, both shell and head are chamfered to make the V-groove.

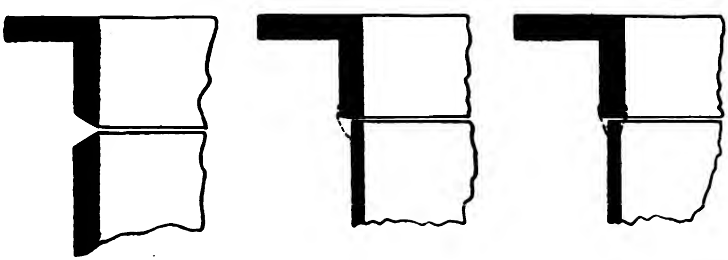


Fig. 65. Welds for Tank Reinforcing Rings

High-Pressure Tanks. When a head is put in, as shown in Fig. 64, both the edge of the flange and the edge of the shell are chamfered. This type of head is the best for high-pressure tanks because the weld is in tension.

This method also applies to the welding of two cylindrical shells end to end in making tanks of such dimensions that one single sheet of steel is not large enough to make a complete shell.

Tank Rings. In welding angle-iron rings to tanks of the same thickness, it is necessary that the edges of both ring and shell be

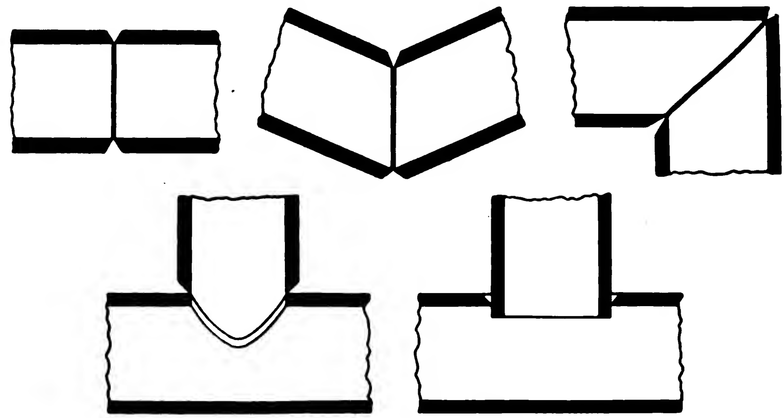


Fig. 66. Various Pipe Joint Welds

beveled as at the left, Fig. 65. Two methods of welding heavy rings to lighter shells are shown at the middle and right. The inside weld at the right should be only enough to smooth off the joint.

Fig. 67. Welds for Pipe Heads

If too much heat is applied from the inside there is likely to be trouble from warping or buckling. Rings should always be tacked to prevent bowing, twisting of the rings, and buckling of the shell.

Tubes and Pipes. Various tube and pipe welds are given in Fig. 66.

The methods for closing the end of a pipe with a head are shown in Fig. 67. The first is the easier and stronger of the two.

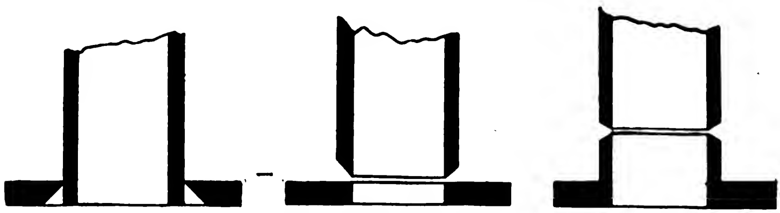


Fig. 68. Welds for Pipe Flanges

Three methods of welding flanges to pipe are shown in Fig. 68. The first method is easier to weld than the second; but the latter

is the stronger. The third method is the best method of welding flanges to pipe, but is, of course, a special type of flange.

Welding Heavy Steel Forgings and Steel Castings

Preparation. In welding heavy steel sections, such as crankshafts, axles, and the like, the weld is prepared by grooving or beveling from both sides. This is done because it is easier for the operator to do the work and for the sake of economy, because by beveling from both sides less filling material is necessary and, consequently, less time and gas are needed.

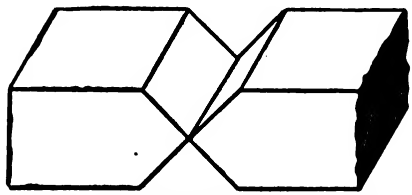


Fig. 69. Preparation of Heavy Forgings for Welding

Square Sections. Square or rectangular sections of forgings are best prepared by beveling half way through from each side, Fig. 69. After the welding has been carried on from one side, the piece turned over and the welding completed from the second side, there will probably be a slight bow, or curve. In the case of forgings, this is not objectionable, because the work can be, and, in fact, should be, reheated and straightened. The reheating in the case of forgings is beneficial to the grain of the material and the strength of the weld. With castings, however, this bending is not possible. Therefore, to keep the work in alignment, it is best to prepare the work as shown in Fig. 70. The welding is carried on two-thirds of the way through from the first side, and then finished by turning over and working from the second side.

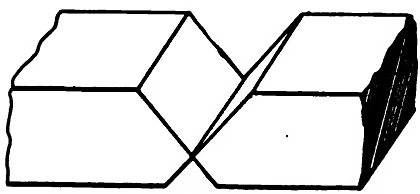


Fig. 70. Preparation of Heavy Castings for Welding

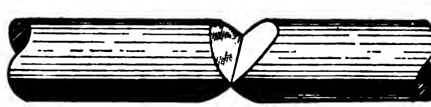


Fig. 71. Preparation of Round Sections for Welding

Round Sections. Round or elliptical sections should be prepared by beveling the ends to a wedge as indicated in Fig. 71. They should never be turned down to a point. By preparing the pieces as shown

in the illustration, the welder will have a flat surface to build his weld upon. If the work were prepared to a point, the filling material when added would have no surface to lie upon and would run down in drops, necessitating burning or melting away when the work is turned over, and probably resulting in a weak weld with considerable oxide.

Expansion and Contraction. Expansion and contraction will probably cause very little trouble to the operator in the case of shafts and other heavy pieces that are not connected. The only difficulty the operator will encounter in these cases will be the possible bending, which was noted above, when welding from two sides. However, if the broken part is confined by rigid members, the work should be handled either by pre-heating, or one of the other methods recommended and explained under Expansion and Contraction, pages 36 to 40.

V-Blocks. When welding shafts, it is advisable to line them up in position on V-blocks, so that they may be turned over and still kept in alignment, Fig. 72.

Fig. 72. "V" Blocks for Welding Shafts

Heavy Welding Section. In the case of a heavy section select the proper size welding head and a piece of welding rod of the correct analysis for the particular work at hand, and place the work in alignment.

If the section is over or about one inch, it should be pre-heated by means of a gas or oil burner until it is at a red heat. This will save oxygen and acetylene, and will bring the material to a temperature at which it will be more receptive to the action of the welding flame and thereby insure a more homogeneous weld. If not objectionable to the operator, it is advisable to let the pre-heating burner play on the work while the welding operation is going on, taking care, of course, that the materials of combustion of the pre-heating burner do not strike the molten metal and have a detrimental effect on the weld.

The welding flame is first played on the edges at the bottom of the groove until they are in a molten condition. The flame is then momentarily withdrawn to allow them to flow together and "set", and form the bottom of the weld. When a perfect union of the bottom is secured all the way across, the welding rod is brought into use. By playing the flame around the welding rod and the edges of the weld instead of directly on the welding rod, it is possible to bring them to a fusing temperature at the same time. The rod is then gradually added to the weld, layer by layer, until the entire groove has been filled up. The welding rod is kept plunged into the molten metal all the time to prevent oxidation. Any oxide that forms during the welding is floated to the top and removed by scraping with the welding rod, or by blowing away with the force of the welding flame. The welder must be careful that he does not allow the molten metal to run over the sides of the weld. Each layer is added in such a way that it extends slightly beyond the end of the groove. Then, from time to time, as the groove is filled up, the operator smooths down the two ends.

Hammering. As each section, about $\frac{1}{4}$ inch thick, is added to the groove, the operator stops the welding operation, heats the work to a bright yellow, and hammers the weld lightly but rapidly to give it as fine a grain as possible. After the weld has been completed, it is either hammered or annealed, as directed on page 45.

CAST-IRON WELDING

General Considerations. Many defects are experienced by the beginner in welding cast iron because of its peculiar properties. The two principal faults noticed are the production of hard, glassy, and brittle metal in the weld, and subsequent cracks, breaks, and checks either in the weld or in the adjacent metal, owing to excessive internal strains set up by unequal contraction. Both are serious defects, and the liability of their occurrence is so great that proper preventive methods should be continually borne in mind and applied while welding this material.

Oxidation. Cast iron melts at about 2000° to 2190° F., and iron oxide melts at about 2450° F. The oxide is formed, however, at low temperatures, a bright red heat being sufficient to cause the combination of oxygen from the air with the iron of the casting.

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It is not possible to melt this oxide and flow it from the weld, so it remains in the casting in the form of thin flakes or crust. This not only prevents the alloying of the molten metal, but also combines it with the free carbon and is, consequently, conducive to the formation of white iron. Therefore, this oxide must be removed or destroyed.

Expansion and Contraction. Cast iron is absolutely lacking in elasticity, and its tensile strength is very low. In preparing work for welding, it is always necessary to take fullest precautions against the bad effects of expansion and contraction. Expansion and contraction should be treated with more importance in the welding of cast iron than in any other metal.

When the internal strain produced by contraction is greater than the tensile strength of the section to which it is confined, failure will occur. When the strain is not great, but still exists, the resistance of the section to external stresses is reduced in proportion. Thus a casting may appear to be normal after welding but the excessive internal strains caused by the welding process may make it fail at the slightest shock.

One of the three general methods of coping with the forces of expansion and contraction, which are given on pages 36 to 40, must be used when welding cast iron. The proper method to pursue is determined by the size and shape of the casting and the nature and location of the break. A very large percentage of the failures due to shrinkage cracks may be prevented by an intelligent anticipation of the forces of expansion and contraction and the proper handling of the work to overcome these.

Pre-Heating. Pre-heating should be used to some extent in all cast-iron welding. If the piece is small and the break is so located that it is not necessary to consider expansion and contraction, the blowpipe should be played upon it until the chill is removed from the casting. If the casting is large, an oil or gas burner, or charcoal fire can be used. In a large casting this preliminary heat treatment not only favors the execution of a good weld but also requires less oxygen and acetylene because of this large volume of heat from a cheap source, thereby reducing the cost of welding.

Welding Rods. The success of cast-iron welding depends greatly upon the selection of a suitable welding rod. It has been proved time and again that hard, brittle, and weak welds have been

produced for no other reason than because inferior filling material was used.

The presence of silicon in proper proportion tends to produce a soft gray-iron weld. It increases the fluidity of the metal, retards oxidation, and prevents decarbonization and blowholes. The success of the filling rod is dependent upon the amount of this element it contains. From 3 to 4 per cent is the average silicon content of good welding rods. The welding rod must be of high-grade cast iron, soundly cast and absolutely homogenous. It must be free from all sand, grit, and rust. For convenience in handling, it is usually cast in 24-inch lengths of three diameters, $\frac{1}{4}$, $\frac{3}{8}$, and $\frac{1}{2}$ inch. In case either a longer or heavier rod is desired, two or more are welded together.

Flux. The principal problem that confronts the welder is to prevent the formation of oxide, and in case it is formed, to reduce it and remove it from the weld. If this is not done, the molten metal will be enclosed in a thin film of nonmetallic material, and any additional metal that may be fused or added will adhere to this film rather than break through it and fuse homogenously with the other metal. It is not possible to satisfactorily break up this film mechanically, therefore it must be reduced to a molten, or slag, condition. To accomplish this a suitable flux is used that will dissolve the oxide.

A flux is not used solely to dissolve the oxide, but also to float off other impurities, such as sand, scale, and dirt. It forms a protecting glaze on the weld and surrounding surfaces and increases the fluidity of the molten metal.

Borax and salt (sodium chloride) are two compounds often used by welders, but they really contain little merit as a flux. Their low fusibility seems to be the only point in favor of their use. Occasionally, they may be employed to advantage in welding heavy sections or burned iron, such as are found in firebox and grate castings, but their function is only that of a cleanser. Both tend to produce hard iron. There are certain flux powders put on the market that contain large proportions of manganese. These powders cannot help but have a hardening effect on the iron. Others contain potassium perchlorate, a virulent oxidizing agent. Still others contain material that chlorinize the weld. Needless to say, powders of this

kind must not be used. It is best to guard against the purchase of such defective mixtures by obtaining flux powders from reliable sources.

It is necessary that the welder learn to apply flux properly. An excess will cause as much trouble as an insufficient quantity. Blowholes may be increased in size and number by using too much flux. Also the molten iron will incorporate certain constituents of the flux if it is applied in excess. The amount to be applied depends upon the flux used. A welder must learn to know his flux as well as his blowpipes.

The powder should be applied regularly by dipping the hot welding rod into it. The quantity adhering is sufficient. Do not throw large quantites into the weld as plenty will be added by the welding rod.

Preparation of Welds. All cast iron over $\frac{1}{8}$ inch in thickness should be beveled or chamfered before welding. If this is not done, it is necessary that the metal be burned out by the blowpipe in order that complete penetration be assured. This is bad practice as it is almost impossible to do it without either changing the state of the metal in the groove due to the forced flame, or causing partial adhesion. The chamfering should be a little wider than on other metals for the reason that it is good practice to introduce as much special metal from the welding rod as possible.

The chamfering can be done by various means. If the casting is light and broken in two pieces, it may be taken to an emery wheel and the edges ground off. If the casting is too heavy to move, a portable grinder or cold chisel and air or hand hammer can be used. If the casting is only cracked, the cold chisel and air or hand hammer are the most satisfactory tools to use.

After the weld has been beveled satisfactorily, the adjacent metals should be cleaned about $\frac{1}{4}$ to $\frac{1}{2}$ inch from the edge. This is important, because all dust, sand, scale, etc., should be removed from the welding zone.

To Prevent Crack from Extending. If the defect in a casting is a crack that shows a tendency to extend upon heating, a hole should be drilled in the casting a short distance from the end and in the direction the crack would follow. The crack will not extend beyond this hole, and the hole can be very easily filled in.

Welding Process. Although the melting point of cast iron is not high, the total heat required to bring it to fusion is great, therefore a blowpipe of large size is used. The speed of welding is increased considerably, and the selection of the proper size blowpipe is influenced by the extent of the pre-heating.

Cast iron melts very rapidly after the fusing point is once reached, and when molten is extremely fluid. Because of this property, the welding should be carried on horizontally, otherwise the metal will flow toward the lowest point. This is not desired, because it will tend to produce adhesion. In case it is not possible to arrange the casting so that the weld will be horizontal, the welding must be started at the lower end, and skill must be used to prevent the too rapid advance of the molten metal. It is very difficult to produce vertical and overhead welds because of the fluidity. In welding thin sections of cast iron, the rapidity with which it melts and its fluidity often cause the metal to sink, bulge downward, or drop in. Consequently, it is necessary that close observation and careful manipulation be used on this kind of work.

Flame. The incandescent jet of the oxy-acetylene flame should never impinge on the molten metal. The tip of this jet should be held at a distance of $\frac{1}{8}$ to $\frac{1}{2}$ inch from the metal according to the thickness. The molten iron is seriously influenced by the high temperature of this jet and may become oxidized and decarbonized. This must be rigidly observed except when it is necessary to use the jet to burn out sand holes, blowholes, etc.

Manipulation of Blowpipes and Welding Rods. Because cast iron fuses rapidly when once the melting point is approached and the molten iron is extremely fluid, the circular or oscillating motion imparted to the blowpipe need not be so pronounced. The welding of cast iron is nothing but a succession of overlapping miniature pools, or puddles, of molten metal.

The weld is started by playing the blowpipe on the two lower edges of the weld. The flame should strike the weld almost perpendicularly, because if the blowpipe is inclined, the flame will blow the molten metal ahead of the weld, and adhesion will result. When at the proper temperature, these edges are fused together without any filling material by the aid of a little flux. It is important that this first operation be carefully carried out, as the strength of

the weld is dependent upon a good bottom and top. When th first fusion has been successfully obtained, the welding rod is broug into play and the high silicon metal is added. With each additio

Fig. 73. Warm Welding Rod Is Dipped into the Flux before Each Addition to the Weld

Fig. 74. For Cast-Iron Welding, Blow-pipe and Welding Rod Are Held Almost Vertical

the welding rod is previously dipped into the flux can, and th adhering flux introduced in the weld, Fig. 73. As the welding o cast iron is a comparatively rapid procedure, the welding rod ca

Fig. 75. Dirt May Be Scraped off by Means of the Welding Rod

Fig. 76. Welding Rod Should Not Be Held Too Far from Welding Zone

be held more vertically and added faster, Fig. 74. In welding "dirty" iron it is sometimes convenient to hold the rod in a horizontal position and scrape out sand, carbon, or any other dirt by means of the rod

as soon as it appears, Fig. 75. In this connection, it may be added that the welding rod should be used constantly to work out impurities and blowholes. The welding rod should be melted as much as possible in the molten metal of the weld. It should be plunged into this liquid, and the fusion carried out by playing the flame around it. The welding rod should not be held too far from the welding zone, Fig. 76, nor should it be added to the weld drop by drop as shown in Fig. 77.

As a section of the weld is finished, it should be scraped or rubbed with a file while red hot, Fig. 78, to remove the film of flux, scale, sand, and dust that is present. This film if allowed to cool becomes very hard and is quite resistant to machine tools. Regardless of the

Fig. 77. Welding-Rod Should Not Be Added Drop by Drop

Fig. 78. Scraping Finished Weld with File to Remove Scale

quality of metal beneath it, many welds have been rejected because of the hardness of this superficial surface.

If the weld is carefully executed and the surface is cleaned, it will look like the left of Fig. 79, while if poorly executed and not cleaned, it will look like the right of Fig. 79.

Never go over a weld the second time if it can be avoided. In case it is absolutely necessary, always add fresh metal from the welding rod, as a failure to do this will cause a loss of silicon in the weld and destroy its value to the metal.

Always perform the welding as fast as possible, because extended heating will tend to lower the silicon content of the weld, with the resultant formation of hard iron.

Blowholes. Blowholes occur frequently in the weld and are particularly troublesome if in the bottom of the weld. Their presence can be caused by mechanically enclosed gases or by improper blowpipe handling. When blowholes appear in the weld, they should be instantly worked out. This may be done by forcing with the welding rod and applying flux. In beginning a weld, it is necessary that the presence of blowholes be guarded against, as it is difficult to work out a blowhole at the bottom of the weld after it is finished. Occasionally, in going over a weld, a blowhole is discovered; this must first be

Fig. 79. Appearance of Cast-Iron Welds That Have Been Properly (left) and Poorly (right) Executed

burned out by the white jet of the flame and then worked over with the welding rod.

After-Treatment. The rate of cooling materially influences the structure of the metal in the weld. If rapid cooling is allowed, hard brittle iron is produced. If slow cooling is employed, soft gray iron is formed. Internal strains and stresses may be distributed and adjusted or, in some cases, eliminated by proper cooling and annealing.

Castings which are not large or which it has not been necessary to pre-heat extensively may be satisfactorily annealed by playing the blowpipe on the weld and surrounding metal until it is at a bright red heat. The heated portion is then covered with asbestos

paper, cinders, or other nonconducting material that will retain the heat and protect the castings from air currents. For small castings, a barrel or bin of hydrated lime and fiber asbestos is recommended. This makes a convenient arrangement and is very satisfactory as an annealing agent.

Where it is necessary to heat the entire casting in a charcoal or coke fire, the same temporary furnace used for pre-heating may be used in annealing. After the welding has been completed, the casting should be covered over with hot coals and ashes, and the furnace should be bricked up, i. e., all large air ports closed, the top covered with asbestos paper, and the casting allowed to cool with the fire.

The castings should never be removed from the annealing fire until they are entirely cold. This is imperative, as cold air currents on the warm castings may cause checks or cracks. In some cases, 12 to 24 hours are required for satisfactory cooling.

Use of Carbon Blocks. In case it is not possible to line up the weld horizontally, or it is necessary to fill in a wide hole, carbon blocks or steel plates are sometimes used to dam or retard the flow of the metal.

MALLEABLE-IRON WELDING

Malleable Iron. Malleable cast iron, or malleable iron, as it is commonly called, is used extensively in castings where toughness, malleability, and resistance to sudden shock are required. The characteristic that gives malleable iron its greatest value as compared to gray iron is its ability to resist shocks. Malleability in a light casting, $\frac{1}{4}$ inch thick and less, means a soft pliable condition and the ability to withstand considerable distortion without fracture, while in the heavy section, $\frac{1}{2}$ inch and over, it means the ability to resist shock without bending or breaking.

In the manufacture of malleable-iron parts, white iron castings are packed in annealing pots with suitable material, such as mill-scale borings, etc., and subjected to a cherry red heat for from 48 to 96 hours, after which they are allowed to cool slowly. During this annealing process, the material in which the castings are packed absorbs the carbon from the surface of the casting. In this way the surface becomes really a steel, while the inside, or core, becomes gray cast iron.

Straight Weld Not Possible. When malleable iron is heated to a fusing heat the malleable properties are destroyed and cannot be regained.

Brazing Malleable Iron. The most successful method of joining malleable iron with the oxy-acetylene blowpipe is by brazing with Tobin bronze. While this gives a joint of different color, yet the strength, malleability, and machining qualities are satisfactory.

The two pieces to be joined are beveled as for cast-iron welding. The edges are brought to a point just below fusion, great care being taken that they *do not* become fused. When the edges are at the right temperature, a rod of Tobin bronze is fused into the groove with the aid of a good brass flux. The work should be carried out by using a flame having a slight excess of acetylene and should be done as rapidly as possible to prevent oxidation of the bronze.

ALUMINUM WELDING

General Considerations. When aluminum approaches its melting point, it does not change color in ordinary light, but retains its silvery appearance even when in the molten condition. When molten, it is very fluid and is, therefore, rather difficult to control under the welding flame.

Oxidation. Aluminum oxidizes very easily when in a molten condition, forming an oxide that melts at about 5400° F. The oxide, therefore, cannot be penetrated by means of the flame, but must be removed either chemically by means of a flux or mechanically by means of a paddle.

Expansion and Contraction. Because of the high heat conductivity of aluminum, expansion and contraction do not give great difficulty owing to localized heating. However, because aluminum expands greatly and is very weak when at high temperatures, contraction strains are very likely to produce cracks or checks unless the work is allowed to cool evenly and slowly. It is advisable to pre-heat aluminum castings to between 300° and 400° F. to aid the distribution of the heat and prevent warping.

Welding Rod. In welding sheet aluminum, such as automobile bodies, the welding rod should be clean material of the same alloy as the sheets that are being welded. If wire cannot be obtained of the same composition as the sheets, narrow strips should be

sheared from the sheets themselves and used for a filling material. The strips should be sheared about as wide as the sheets are thick.

For aluminum castings, such as crank cases, a good grade of aluminum wire about $\frac{1}{4}$ inch in diameter should be obtained. Welders should not use the cheap solders or very low fusing cast rods that are sometimes sold, and for which great claims are made. The operator will readily appreciate that when these materials are added to the weld they will merely adhere to the sides, because, while the filling material will be quite fluid, the edges of the weld will not be at a fusing temperature.

Flux. It is impossible to weld sheet aluminum without the use of a good flux to dissolve the oxide and float it to the top as a slag. In cast-aluminum work a paddle may be used to accomplish this result, but such a device is not practical for sheet work. The flux may be applied either by dipping the warm welding rod into the flux powder or by mixing the flux with water to form a paste and applying this to the joints by means of a brush. Care must be taken that too much flux is not used, because an excess will produce a porous weld and one with a poor surface. After the work has been completed the flux should all be washed off with warm water.

Flame. In order to be sure that an oxidizing flame is not being used, it is permissible and advisable to use a flame showing a slight excess of acetylene. This flame will also have the advantages of being slightly larger in volume than the neutral flame and of lower temperature, this last feature being helpful, especially to the new operator.

SHEET-ALUMINUM WELDING

Sheet-aluminum work may be handled very similarly to sheet steel as regards preparation and allowance for expansion and contraction.

Types of Joints. For light sheets under $\frac{1}{16}$ inch the flange weld should be used. The butt joint may be successfully made on light sheets by an experienced operator, but there is a great deal of danger of burning through and having to fill up holes, which will leave a poorly finished weld.

For sheets above $\frac{1}{16}$ inch the butt weld is found to be the best, and for sheets above $\frac{1}{8}$ inch the edges should be beveled the same as for steel plates.

Welding Process. Select the proper size blowpipe and welding rod, a good flux, and arrange the work for welding. Start the welding by playing the secondary flame of the blowpipe over the parts surrounding the weld, to warm them up slightly. If the flux is to be applied with a brush, it should be done at this time, because the heat will evaporate the water and leave the solid flux evenly distributed over the weld. Welding should then be started from ½ to 1 inch from the end—not at the end. The blow pipe should be handled about the same as for steel welding, care being taken that the inner cone of the flame does not come in contact with the metal. For very thin sheet welding it is not necessary to give the circular or oscillating motion to the blowpipe; it is merely necessary to move it forward in a straight line.

On the heavier work, however, the same motions should be used by the welding operator as are used for steel. The welding wire is best held directly in line with the weld and always in contact with the metal just ahead of the blowpipe. If the wire is not in contact with the edges when they become molten, they will be likely to curl up or draw away instead of flowing together. After the main weld has been completed, the operator should go back and weld the short section that was left unwelded at the very beginning. After the work has cooled the flux should be removed by washing off with warm water.

Re-Welding. The operator should be careful that the weld is completed as he goes along, so that he will not have to go back to make repairs or to do re-welding. If it is necessary to go back over a weld, cracks or checks are very likely to result because of the weak condition of the metal when it is at a fusing temperature. If it is necessary to re-weld a certain portion of the joint, the surface should be chipped off so as to present a clean surface for the new filling material to fuse to. Following the suggestions already made, the seam and the surrounding surfaces should be thoroughly preheated before the welding is started to prevent cracking as much as possible.

After-Treatment. If possible, welds in aluminum sheet should be reheated evenly to equalize any internal strains. Then, after the weld has become *cold*, it should be hammered to improve the grain of the metal in the weld.

Cast Aluminum Welding

Aluminum Castings. Most aluminum castings are alloys of aluminum, zinc, and copper; the alloy being added to the aluminum to give it a higher tensile strength and increase its resistance to shock. The welding of cast aluminum is different from that of sheet aluminum and resembles in a general way the welding of cast iron. Oxidation is taken care of by using flux or by scraping the oxide out by means of a paddle. The second method is faster and is the one preferred by most operators.

Paddle. The paddle is made by flattening down the end of a ¼-inch steel rod to a smooth short flat blade about ⅜ inch wide. The handle may be left straight or bent to suit the operator. The paddle should be used only when just below a red heat. If it is cold, the molten metal will stick to it, and if it is too hot it will burn and the metal will stick to the roughened surfaces.

Preparation. Sections if over ¼ inch in thickness should be chamfered before the welding is started. Sections thinner than this may be worked without beveling. The old metal may be scraped out by means of the paddle in order to give a clean bright surface for the new material to be added to.

Pre-Heating. Because aluminum alloy castings are not very ductile and are weak when at a high temperature, expansion and contraction must be taken care of. This is handled in the same general way as in the case of cast-iron work. The casting should be pre-heated either partially or wholly by some *slow* heating agent, such as a gas burner or mild charcoal fire. The pre-heating should never be carried to too high a temperature, because of the danger of the metal sinking, or caving in. The casting will be sufficiently warm for welding when a file or chisel will mark it easily, or when a piece of dry pine stick is charred upon being drawn across the heated section.

Welding Process. When a flux is used in welding cast aluminum, the work is carried on in the same general manner as in welding cast iron, and the same general precautions regarding the peculiarities of the metal are to be observed as in welding sheet aluminum.

If a paddle is used to break the film of oxide and scrape it out of the weld, the edges are brought to a state of fusion for a length of about 1 or 1½ inches. The paddle is then used to scrape out the weld

to make a slight bevel and present clean surfaces for the filling material to be added to. The welding rod is then introduced into this groove. The paddle is used continually to work in the filling material, scrape off any oxide that forms, and then to smooth off the surface of the weld. After a small section of the joint has been completed, the casting is turned over, and the weld for this length is smoothed off on the underside by means of the blowpipe and paddle. The welding is carried on in this manner, section by section, until the entire joint is completed. If the weld were completed on the first side and then turned over and smoothed its entire length on the underside, cracks would develop, and the casting would warp out of shape.

After-Treatment. When the welding has been completed, the casting should be reheated slightly to remove any local strains and should then be covered over with asbestos paper to protect it from drafts and to allow it to cool very slowly. If the cooling is carried on rapidly, or if air currents are allowed to strike the casting, it will very likely crack either in the weld or some weak section.

COPPER WELDING

General Considerations. Because of the high thermal conductivity of copper, the heat from the blowpipe is conducted back into the work rapidly and is lost to the weld. This necessitates the use of a large size welding head or the use of an auxiliary source of heat to assist the welding flame in the case of heavy work. When at high temperatures, copper is weak in tensile strength the same as aluminum. Because of these two factors the effects of expansion and contraction must be carefully considered, so that the work will not cool too rapidly after the welding has been completed, and will not crack at high temperatures.

Oxidation. Copper oxidizes quite readily, forming an oxide which dissolves in the molten metal and changes the structure of the weld. The amount of oxide that can be absorbed is very high, consequently great care must be exercised to keep the absorption at a minimum. Welding rods containing a small percentage of phosphorus and suitable fluxes are used to counteract the oxide and reduce it as much as possible.

Welding Rod. For successful copper welding, it is necessary to use electrolytic copper containing about one per cent phosphorus,

supplied in coils and drawn rods. The cast copper alloy rods that are on the market are not satisfactory, because the structure and composition will vary even in a single rod to such an extent that a homogeneous weld cannot be made.

Flux. In welding copper the flux is used not only to cleanse the weld, but also to protect the metal adjacent to the welding zone from the gases of the flame. When welding sheet copper it is advisable to make a paste of the flux by adding water and to coat the metal about one inch adjacent to the edge of the weld. When this flux is melted, it will form a glassy film that will protect the metal from the gases of the flame and the air surrounding the work. Additional flux is added to the weld as the work progresses, by dipping the warm rod into the dry flux, as in welding other materials.

Flame. It is very important that the neutral flame be maintained at all times, and the operator should use great care in adjusting his gases, so the flame will not have an excess of acetylene nor be oxidizing. Because of the peculiar properties of the metal, the gases of the reducing flame are very likely to be absorbed, and because of the ease with which the metal oxidizes, oxidation is liable to occur if the flame contains an excess of oxygen.

Preparation. Sheets that are less than $\frac{1}{8}$ inch in thickness may be butted together without beveling. Sheets heavier than this should always be beveled, and no attempt should be made to depend upon the flame to penetrate this heavier thickness. In all cases of copper welding, the edges to be joined and the material adjacent to the edges should be scraped or filed to present a clean surface for the filling material to be added to.

Welding. The edges of the metal surrounding the weld should be raised to a fairly high temperature before the actual welding is started. On small pieces and light-weight work, this may be done by means of the welding blowpipe, but for heavy work and long welds, it is best to do this by means of a gas or oil pre-heating burner. After the work has been brought to a high temperature, the welding should be started at one end and should be performed as rapidly as possible. The welding rod and edges of the weld should reach the state of fusion at the same time, so as to prevent adhesion and to insure a good weld. This feature is harder to accomplish in welding copper than in other metal, because the heat is conducted back into

the rod or into the work very rapidly, necessitating very careful and skillful manipulation of the blowpipe and rod. The blowpipe should be held almost vertical, about the same as in the case of cast-iron welding. If held at too great an angle, the molten metal will be blown ahead and will adhere to the cold edges of the weld in advance of the blowpipe. The inner cone of the flame should never come in contact with the metal, but should be held about $\frac{1}{8}$ or $\frac{1}{4}$ inch above the surface of the weld to prevent burning the metal. The oscillating motion should be carried on about the same as in steel welding but a little more rapidly, and should consist of smaller circles. The welding rod should be plunged into the molten metal all the time and should be continuously moved around or stirred, so that it will be thoroughly incorporated and will bring the oxide and slag to the surface. The weld should be built up above the surface of the sheets, so there will be enough material to allow for hammering after the welding has been completed.

Re-Welding. In case it is necessary to re-weld a portion of the joint, it is necessary that the old material be chipped out and new material added.

After-Treatment. After the welding operation has been completed, the work should be heated very carefully and evenly until it is almost at a bright red heat. The weld should then be hammered while hot, so that the strength of the joint will be increased as much as possible. After the hammering has been finished, the work should be again reheated to a red heat and cooled quickly by means of an air blast or chilled by plunging in water. Care must be exercised in this operation if the work be a casting having confined, or rigid members, so that cracking, or checking, does not occur.

BRASS AND BRONZE WELDING

General Considerations. Brass and bronze are both alloys of copper, brass consisting mainly of copper and zinc, and bronze of copper and tin. Both brass and bronze are welded in about the same general manner as copper, but because of the peculiar properties of the alloying metals, zinc and tin, it is necessary that they receive certain variations in welding.

Oxidation. In both brass and bronze, the alloying metal is greatly affected by the high temperature of the flame, and the material

will be subject to a loss of zinc or tin, unless proper precautions are taken. These metals will combine with the oxygen and pass off as white vapor, and leave a weld of different composition and color.

Absorption of Gases. The molten metal in both brass and bronze absorbs certain gases very readily, and unless this absorption is counteracted, the weld will be spongy and weak. This may be taken care of by using a suitable welding rod and flux.

Welding Rod. Because of the varying composition of brass and bronze, and because of the loss of the alloying elements when welding, it is practically impossible to produce welds of the same color as the original material. When welding brass, a good grade of drawn brass will be found most satisfactory, and in the case of bronze, a good drawn bronze, such as manganese or Tobin bronze. The cast rods that are on the market are not satisfactory, because it is quite impossible to cast a rod having the same composition throughout.

Flux. The flux used for brass and bronze is practically the same as that used for copper. It should be applied by dipping the warm welding rod into the powder and adding it to the weld in this manner. It is not necessary to use as much flux as in welding pure copper, and care must be taken that an excess is not used, because the weld may become porous.

Flame. A neutral flame must be maintained at all times for the same reasons as explained under copper welding. The blowpipe should be held between $\frac{1}{8}$ to $\frac{1}{4}$ inch from the metal. If the flame is held too close in the case of bronzes, the concentrated heat will cause a segregation or separation of the tin from the copper, and it will be practically impossible to again unite these elements.

Preparation. The edges of the metal for a thickness of less than $\frac{1}{8}$ inch may be merely butted together and welded, while for metals above this thickness the edges should be beveled or chamfered, so as to allow penetration of the flame and insure a good weld.

Welding. Because of the high conductivity of these materials, it is best that they be pre-heated to bring them to a suitable condition for rapid welding. Care must be taken when pre-heating bronze that it does not get too hot, because it is weak at high temperatures and is liable to break or crack under its own weight. The welding is carried on in about the same manner as for copper, and the blowpipe is handled in practically the same way. The welding

rod should be in contact with the edges of the metal at all times, and the blowpipe should be played constantly on both the rod and the edges of the metal to keep them at the same temperature in order that adhesion may be prevented.

Re-Welding. Re-welding should be avoided, but if it is absolutely necessary to re-weld the work, the section should be chipped out, and new material added, as in the case of copper.

After-Treatment. Both brass and bronze should be annealed after welding by reheating evenly, and then allowed to cool slowly. Brass may be improved by hammering before the final annealing. Brass of low zinc content, i.e., red brass, should be hammered while hot, while brass of high zinc content, i.e., yellow brass, should be hammered cold.

MISCELLANEOUS PROCESSES

CUTTING

Cutting In Automobile Repairs. The oxy-acetylene cutting blowpipe finds considerable application in the automobile repair shop for beveling the ends of shafts and other pieces of work preparatory

Fig. 80. Beveling Ground Shaft for Welding. The other piece is on the table

Fig. 81. Beveling End of Heavy Square Shaft for Welding

to welding, Figs. 80 and 81, cutting reinforcing plates out of large sheets for frame repairs, altering chassis, etc., Fig. 82. The cutting

blowpipe is capable of doing this work cheaply and quickly, two necessary factors for the successful first-class repair shop.

Principle of Cutting with Oxygen. At ordinary temperatures, steel oxidizes in the air, forming what is commonly called "rust". At a white heat it will oxidize more rapidly, as is seen in the blacksmith shop when pieces are brought to a very high temperature. When steel is heated to a red heat, and a stream of pure oxygen is directed on it, the oxidation takes place more rapidly and more violently and is restricted to the locality upon which the stream of oxygen is played. This localized oxidation is the basis upon which the oxy-acetylene cutting blowpipe operates.

Metals That Can Be Cut. Steel and wrought iron are the only metals that can be cut successfully by means of the oxygen jet. Although cast iron, copper, brass, bronze, aluminum, etc., oxidize easily, nevertheless they cannot be cut.

Fig. 82. Cutting Reinforcing Plate Out of Large Sheet Steel for Frame Repair

When the oxygen combines with the iron, heat is generated. This heat of formation, with the aid of the heat supplied by the pre-heating flames of the blowpipe, brings the oxide to a molten condition. The molten oxide either flows or is blown out of the cut and leaves a fresh thoroughly heated line through the metal for the further action of the cutting oxygen. In the case of steel and wrought iron, the oxide melts at a much lower temperature than the material being cut and therefore blows out without melting the surface of the material. In the cases of cast iron and certain alloy steels, the melting temperature of the oxide is as high and in some cases higher than that of the metal, and therefore melts the edges or freezes in the kurf and so hinders the cutting. Also, in the case of some of these materials, the heat of formation produced by the combination of the oxygen with the metal is not sufficient to carry the cut through the thickness of the work.

Necessary Cutting Apparatus. A complete cutting station, Fig. 83, consists of the following apparatus:

- Cutting blowpipe with set of cutting nozzles
- Oxygen cutting regulator with two gages
- Acetylene regulator with one or two gages
- Adapter for acetylene cylinder
- One length high-pressure rubber hose for acetylene
- One length copper armoured hose for oxygen
- Darkened spectacles, wrenches, hose clamps, etc.

Cutting Blowpipe. In the cutting blowpipe, Fig. 9, page 9, there are usually six small oxy-acetylene flames surrounding a center orifice through which pure oxygen is directed. The six heating jets are used only for the purpose of bringing the edge of the material to a temperature at which the jet of pure oxygen will unite rapidly with the steel, as explained above.

Cutting Nozzle. There are usually four sizes of cutting nozzles furnished for handling work of various thicknesses, from very thin plate up to material 14 and 16 inches thick. Besides these, some manufacturers also furnish what is known as a "rivet cutting nozzle". This is a thin flat nozzle that can be laid against the sheet, allowing, the rivet head to be cut off close to the sheet.

Fig. 83. Cutting Unit for Use with Acetylene in Cylinders, Mounted on Emergency Truck
Courtesy of Oxweld-Acetylene Company, Chicago

Working Pressure. The necessary pressures of the gas that are required by the different sizes of cutting nozzles and for the different thicknesses of material are given by the manufacturers. It is very important that the operator use these pressures instead of higher pressures because of the increased amount of oxygen used and the consequent high cost of operation, also because the cut will not be smooth if too much oxygen is used.

Care of Blowpipe. If the blowpipe is handled properly there will be very little deterioration. It should only be necessary to clean the replaceable and working parts, repack the valves, and occasionally ream out and true up the nozzles. Care should be taken that the orifices of the nozzles do not become enlarged by reaming, because the heating jets will be made thicker and shorter and the cutting jet will spread rather than leave the blowpipe as a long thin stream.

The blowpipe may be cleaned the same as the welding blowpipe by removing both the acetylene and oxygen hose and connecting the nozzle to the oxygen hose, Fig. 16, page 18, and turning on the oxygen to a pressure of about 20 pounds per square inch, having first the cutting oxygen valve open, then the acetylene needle valve, and lastly the oxygen needle valve. This will allow the large particles to be blown out of the larger passages before they have a chance to clog up the smaller passages.

Regulators. The cutting regulator, in principle, is the same as that described on page 20, but in size it is much larger than the welding regulator and is capable of both a higher delivery pressure and a greater volume.

The acetylene regulator is the same as is used in the welding equipment, and described on page 20.

Care of Apparatus. The regulators and hose should receive the same care and attention as is explained for the welding apparatus on pages 18 to 21.

Instructions for Connecting Apparatus. The regulators and the blowpipe are connected up in the same manner as the welding apparatus, and therefore the operator is referred to pages 22 to 30 for instructions.

How To Light the Blowpipe. (1) Take the blowpipe in hand and open the oxygen cutting valve fully.

(2) Turn the oxygen pressure-adjusting screw to the right until the required pressure for the work to be done shows on the low-pressure gage. (See the maker's chart for the correct pressure.)

(3) Close the oxygen cutting valve.

(4) Open the acetylene needle valve fully.

(5) Turn the acetylene pressure-adjusting screw to the right until a good jet of acetylene issues from the heating orifices. In the case of pressure blowpipes, until the required pressure for the thickness to be cut shows on the low-pressure gage. (See the maker's chart for the correct pressure.)

6. Open the oxygen needle valve one-quarter turn and light the blowpipe by means of the pyro-lighter that is usually furnished.

NOTE—A back-fire might occur if there is not enough acetylene being supplied. If this occurs increase the acetylene supply by turning the acetylene pressure-adjusting screw farther to the right.

7. Adjust the acetylene pressure-adjusting screw to give a slight excess of acetylene to the flame.

8. Adjust the acetylene needle valve to give a neutral flame (see under Flame Regulation, page 25) when the cutting oxygen valve is open.

To Shut off the Blowpipe. In the case of the injector type of blowpipe, first close the acetylene needle valve and then the oxygen needle valve.

In the case of pressure blowpipes, first close the oxygen needle valve and then the acetylene needle valve.

To Cut. With the cutting valve closed apply the heating flames to the edge of the metal, keeping the nozzle at such a distance that the small flames barely touch the metal. As soon as the metal becomes heated to a cherry red, open the cutting valve, raise the blowpipe slightly to increase the distance between the nozzle and metal, and then move it along the surface as fast as a distinct and and clear kurf can be secured. The blowpipe should be held at a constant distance from the work. It should travel away from the operator in order that he may watch the cut advance.

Back-Firing. Occasionally, particles of molten metal will impinge on the nozzle of the blowpipe, or the operator will allow the nozzle to touch the surface of the metal, and the blowpipe will back-fire. When this occurs, first close the acetylene needle valve

and allow oxygen to clear the passage, then open the acetylene needle valve fully and relight. If the back-firing continues, close both the acetylene and oxygen needle valves, cool the blowpipe by plunging in water and relight. Other causes of back-firing are loose internal and external nozzles or dirt on the nozzle seat. These can be eliminated by tightening the nozzles and cleaning the seat. These back-fires are usually only a series of pops or sharp reports, and, as a rule, will not extinguish the flame.

Notes on Cutting. *Heating Flames.* The heating flames should be small to produce smooth cutting. If the flames are too small, the blowpipe is liable to back-fire. If they are large, the top edges of the cut will melt and produce a rough cut.

Speed of Cutting. The speed of the blowpipe travel should be slow enough to allow the oxygen jet to penetrate yet not so slow that the oxygen will be wasted.

Restarting Cut. If the blowpipe travels too fast, and the cut is "lost", it is necessary to shut off the cutting oxygen and apply the heating flames to the point of stopping until the metal is hot enough to start the cut again.

To Cut Round Shafts, Etc. The cutting of round pieces will be made easier if the surface of the work is first chipped with a chisel. This will present a good edge for the cutting blowpipe to bite on.

To Pierce Holes. When piercing holes, a high oxygen pressure is necessary, and the metal must be brought to fusion before the cutting oxygen is employed. The blowpipe is held at a slight angle so the sparks will be blown out of the hole and away from the blowpipe.

Cutting Dirty and Poor Material. If there is considerable rust, scale, paint, etc., on the surface, the cutting will be interfered with by small particles flying against the end of the nozzle and perhaps causing back-firing. To overcome this, the heating flames may be made longer, allowing the blowpipe to be held farther away from the surface, or the scale or paint may be removed by first passing the flame over the line of cutting before the cutting is started.

LEAD BURNING

Different Methods. Formerly, lead burning, or lead welding, was confined to garages and service stations that catered to the electric automobile only, but since the introduction of electric lighting and

starting batteries for gasoline automobiles, lead burning has become one of the works of the repair man in all garages. It is therefore important that the repair man have a sufficient knowledge of this class of work to enable him to handle any work of this nature that may happen to come into his shop.

Up to the time of the recent development of a very small oxy-acetylene blowpipe for lead-burning work, the hydrogen air burner was used by most lead burners. The oxy-acetylene blowpipe, however, is rapidly supplanting the old method and, as a matter of fact, within two years it has become universally accepted as being far superior to the old method in handiness of operation, speed, and consequent economy, and has been adopted by the large battery makers in both their factories and service stations.

Fig. 84. Oxy-Acetylene Lead Burning Apparatus
Courtesy of Oxweld Acetylene Company, Chicago

When an operator accustomed to the old flame tries the oxy-acetylene blowpipe, he is very likely to discredit it at first and claim that it is not satisfactory. However, every operator who gives the oxy-acetylene lead-burning blowpipe a fair trial and uses it in accordance with the methods recommended by the manufacturers

of the apparatus must acknowledge it as being superior to any method he has ever used. Its advantages are emphasized even more emphatically if he returns to the old, slower, and more costly methods.

Lead-Burning Apparatus. A complete lead-burning station for use with oxygen and acetylene, Fig. 84, consists of the following apparatus:

Lead-burning blowpipe with set of tips
Oxygen regulator with low-pressure gage
Acetylene regulator with low-pressure gage
Adapter for acetylene cylinder
Valve-block
Two lengths of high-pressure hose to connect regulators to valve block
Two lengths of small hose to connect blowpipe to valve block

Lead-Burning Blowpipe. To make the blowpipe as light in weight and as handy as possible there are no large valves. Instead, a valve block is furnished for regulating the gases, which may be attached to a bench or a wall. In order to make minor or finer adjustments of the flame, and to allow various size tips to be used on the blowpipe and still maintain a perfect flame, an adjustable injector is provided at the top of the blowpipe within reach of the operator's fingers.

Tips. There are about five sizes of tips supplied for use on different thicknesses and various classes of work, each giving its own special size flame. The oxygen consumption of the various size tips ranges from ½ to 6 cubic feet per hour. For storage-battery work the average consumption is about 2 cubic feet per hour.

Regulators. The regulators supplied with lead-burning apparatus operate on the same principle as the regulator described on page 19, the only difference being that they are of smaller size and especially adapted to small flames.

Operation of Lead-Burning Apparatus. The apparatus is connected in the same general manner as the welding apparatus for which instructions are given on pages 22 to 30. The needle valves on the valve block are used to obtain approximate adjustment of the flame, and then the small thumb-nut on the blowpipe is used to make the finer adjustment. The pressure-adjusting screws should be set to give pressures of about 10 pounds per square inch for the oxygen, and 2 pounds per square inch for the acetylene.

The blowpipe, regulators, hose, etc., should receive the same care and attention as the welding apparatus and for which suggestions are given on pages 18 to 21.

Lead-Burning Process. The oxy-acetylene blowpipe should be handled in such a manner that the flame strikes the work perpendicularly. If the blowpipe is used on a slant, the inner cone will not bring the work to the fusing temperature as rapidly as if held vertically, and the secondary flame, or outer envelope, will be very likely to heat the surrounding metal to such a temperature that it will give way and break under its own weight. When working with the oxy-acetylene flame on storage batteries and the like, the operator should do the burning quickly. He should bring the flame down to the work, fuse the metal, add the necessary burning bar, or filling wire, smooth off the work, and remove the flame, all as rapidly as possible.

Fig. 85. Assembling Terminal Groups

Burning Terminal Groups. When burning plates to terminal bars, a small flame should be used, and the work should be held in a fixture, as shown in Fig. 85. The small ends on the plates should extend up into the terminal bar slots about two-thirds of the way. The burning should be carried on by first fusing the ends of the plates to the bottom of the slots, and then filling up the rest of the slot by adding lead from a coil of wire or a burning bar. After several plates have been burned on in this way, the flame should be moved perpendicularly over the surface to smooth it off and leave a nice finish. The flame should *not be held flat* against the work. It will take longer to smooth off the work, and it will not have nearly as neat an appearance if the flame is used flat.

Burning-On Connecting Links. The terminal poles should extend up into the links about one-third of the way. The flame should be brought down into the hole until the inner cone almost

touches the top of the pole, and the pole fused and united with the bottom of the link as quickly as possible. After a good union has been secured in this manner, the burning bar should be introduced and the rest of the cavity filled up, Fig. 86. When working on links and poles it is advisable to do only part of one pole, move to another for a few minutes, and then come back to the first for a few minutes. This will allow the work to cool off slightly and will prevent breaking down or melting away. When burning this class of work, especially if the lead is old and pitted with dirt and cut by acid, it is advisable to increase the supply of oxygen and use an oxidizing flame when working down in the pocket. This will burn out any dirt and will prevent the blowpipe from puffing out when it is burning in the rare atmosphere that exists in the pocket.

Forms or Molds. Small steel frames, or molds, are found very convenient, especially when working on terminal links. These are shaped to conform to the work and are placed around it while it is burning. They are a great help in preventing the corners of the work from breaking down and melting away and, in this manner, relieve some of the tediousness of the work and allow the operator to work under less strain, and permit the work to be done by men who are not skilled lead burners, but who have occasional work of this sort to do.

Fig. 86. Burning-On Connecting Links

CARBON REMOVING BY USE OF OXYGEN

Old Process of Removing Carbon. Up to within the last few years the methods used for removing the carbon from gas-engine cylinders were very impractical and unsatisfactory. To do this work meant the dismantling of the motor, the removal of all the parts, and the scraping of the cylinder walls by hand. Because this

operation necessitated a great deal of work it was not done, in most cases, until the carbon deposit became very heavy.

Oxygen Process. The introduction of the inexpensive process of removing the carbon by burning it out by means of pure oxygen has replaced the old methods and they are no longer used. This new process is so simple, necessitates so little work, can be done so quickly and cheaply, that it can be employed every few months and, in that way, keep the cylinders free from carbon.

Carbon-Removing Apparatus. Complete apparatus for removing carbon by means of oxygen, Fig. 87, consists of the following:

Carbon-removing handle with flexible tube
Oxygen regulator with low-pressure gage
One length of high-pressure rubber hose

It will be seen from this list that all that is necessary for a garage to have in addition to its welding equipment is the carbon-removing handle with a flexible tube.

Burning Out Carbon. Shut off the gasoline at the tank or just in front of the carburetor and allow the engine to run until it has sucked the gasoline out of the lines. Remove the valve caps and spark plugs from all the cylinders.

Turn the engine over by hand until the first piston is at the *upper end of its stroke* and both its *valves are closed.* Introduce a small quantity of kerosene into the cylinder head by means of an oil can or a piece of saturated waste. Light the kerosene in the cylinder, introduce the end of the flexible tube into the cylinder and allow the oxygen to play on the carbon at a pressure of about 5 pounds per square inch. The carbon deposit will catch fire and will continue to burn as long as there is carbon present. Of course, if the carbon is deposited in patches it will be necessary, after one patch has been removed, to start another by means of kerosene.

Fig. 87. Carbon-Removing Apparatus

After the first cylinder has been thoroughly cleaned, turn the engine over by hand until the piston of the second cylinder is at

its upper stroke with its valves closed, and then proceed to remove the carbon from this cylinder in the same manner.

After all the cylinders have been thoroughly cleaned, clean the valve caps and spark plugs by scraping or by burning off the carbon and then replace them in the engine.

Notes on Carbon Burning. Before burning out the carbon be sure that there is no chance of gasoline being present which might cause back-firing into the intake manifold.

The oxygen pressure should not be too high. Only enough oxygen should be supplied to keep the carbon kindled. Too much pressure will waste oxygen and increase the cost of burning out the carbon.

Too much kerosene must not be used, because there is a chance of the operator burning his hands with the sudden burst of flame that might result.

EXAMPLES OF AUTOMOBILE REPAIR

Pressed-Steel Parts. All pressed-steel parts of automobiles, such as frames, bodies, fenders, axle housings, tubing, etc., should be welded, using a pure iron welding wire for a filling material.

Frames. Almost all frame repairs necessitate a certain amount of dismantling of other parts. The extent of the dismantling depends upon the location of the proposed weld. If the work is to be done under the body, it is best to remove the car body. This is not absolutely necessary, however, because the work can be done by merely jacking up the body several inches to give enough room to do the work, and protect the body from the heat of the welding flame. If the weld is to be done close to the radiator, this should be removed so that the solder will not be melted out, Fig. 88. If the weld is about 12 inches from the radiator, the solder can be protected by placing sheet asbestos over the radiator. In this connection it is well to remind the operator that it is always advisable to cover the parts of the car near the welding with sheet asbestos to protect them from any possibility of the flame or heat getting too close.

Jacks should be placed under the frame and the frame brought into alignment before the welding is started; the jacks should not be removed until the weld has been completed and has become thoroughly cooled.

It is always advisable to bevel the work by chipping. In the case of frames of light-weight pleasure cars this may be dispensed with if the operator is careful to penetrate through the thickness of the material. All paint, dirt, and grease must be scraped off next to the weld from both the inside and outside of the frame before the welding is commenced, to prevent dirt from being incorporated in the weld.

A reinforcing plate should be prepared about the same thickness as the frame, as wide as the frame is high, and about three times

Fig. 88. Radiator Is Removed if Welding Flame Is Near It

as long as it is wide. This may be cut out of sheet steel by means of the cutting blowpipe, Fig. 82, page 77, or by means of a hack saw. The blowpipe is the quickest and easiest method, especially for cutting plates for curved frames such as are used on pleasure cars. The weld will look better if the reinforcing plate is welded on the inside of the frame, but in some cases that is impossible without a great deal of extra dismantling. It is then allowable to weld it on the outside.

The welding should start at the lower end of the frame and move upward as explained under Vertical Welding, page 31. The

two flanges of the channel should then be welded, starting at the corner and moving toward the edge. When welding the lower flange, the work should be carried on as explained under Overhead Welding, page 31. After the frame has been welded, the reinforcing plate should be welded on by welding the horizontal edges first and the ends last.

The weld will be materially strengthened if it is hammered during the process of welding, as explained under Hammering, page 46.

Fig. 89. Badly Bent Frame

The oxy-acetylene blowpipe is also very valuable in straightening frames that have become bent in accidents. A frame of this sort is shown before and after straightening in Figs. 89 and 90.

Bodies and Fenders. Bodies and fenders that have been torn can be successfully welded if the operator uses his best efforts and is careful.

Fenders, as a rule, do not present very much difficulty because the break usually extends to the edge. It is advisable to pack wet asbestos along both sides of the weld to prevent buckling as much as possible, Fig. 91. The wet asbestos will absorb the heat and will not allow it to be conducted back into the sheet.

Bodies should be welded in a similar manner when they ar torn. If possible, it is advisable to bend the edges outward slightl

Fig. 90. Frame after Heating with Welding Flame and Straightening

before welding. Then as the weld is cooling, hammer it flat to compensate for the contraction that takes place.

If a patch must be welded in, it should be prepared either round or oval, or should have rounded corners of large radii. The patch should be dished to compensate for the contraction that will take place when the work cools. The hole in the body and the patch should be trimmed so they fit well. When the patch is ready, it should be tacked in place. The welding should be carried on as quickly as possible. After the weld has

Fig. 91. Welding Torn Fender. Wet Asbestos Along Weld Will Prevent Buckling of Light Sheets

been completed, the flame should be played on it to heat it evenly. As the weld starts to cool, the center of the patch should be heated

Fig. 92. Broken Front Axle

Fig. 93. Welded Front Axle

Fig. 94. Crankshaft in Crankshaft Jig Table for Welding

slightly so that it will stretch easily and compensate for the contraction taking place in the weld.

Springs. The welding of springs should not be attempted except for emergency repairs to allow the car to be used until a new spring can be obtained. A steel welding rod of low-carbon content

Fig. 95. Pre-Heating Crankshaft with Gas Burner

Fig. 96. Welding Crankshaft. Note that the Pre-Heating Burner Is Used to Assist the Welding Flame

should be used for filling material. No attempt should be made to re-temper the spring, because the average garage is not equipped to handle work of that nature and, consequently, the spring is very

Fig. 97. Welded Crankshaft

likely to be worse if a poor job of tempering is done than if tempering is not attempted. It is well to pack wet asbestos around the spring next to the weld to prevent the heat being conducted back into the rest of the spring.

Shafts and Axles. Shafts and axles are alloys of nickel, nickel and chromium, or chromium and vanadium. It is desirable to have the filling material of the same composition as the shaft or axle, but this is practically impossible. The most suitable welding rod

Fig. 98. Broken Malleable-Iron Rear-Axle Housing

that can be obtained for this work is one containing about 3.50 per cent nickel, or one containing about 0.20 per cent vanadium and 0.12 per cent chromium. This latter steel is more difficult to handle under the welding flame, so that most welders prefer the 3.50 per cent nickel rod.

Square shafts, Figs. 92 and 93, and round shafts, Fig. 80, page 75, should both be beveled by means of the cutting blowpipe or by grinding, and should then be placed in alignment or in suitable jigs, Fig. 94. A gas or oil pre-heating burner should then be directed

Fig. 99. Repaired Malleable-Iron Rear-Axle Housing

on the point of welding, Fig. 95, and the work heated to a red heat before welding is started. The welding should then be carried on, Fig. 96, according to the instructions given under Welding Heavy Sections, page 58. After the welding has been completed the work should be reheated and any straightening done that is necessary.

The weld should then be heated up evenly, covered over with sheet asbestos, and allowed to cool slowly. The finished weld is shown in Fig. 97.

Axle Housings. If the housing is of pressed steel, it will not present any particular difficulty to the welder, except that he will have to take care that it does not get out of alignment. A pure iron welding wire should be used, and the work should be prepared and carried on as explained under Light Sheet-Steel Welding, pages 46 to 50

If the housing is of malleable iron, Figs. 98 and 99, it should be beveled, placed in alignment, and then *brazed*, using Tobin bronze for a filling material as explained under Malleable-Iron Welding, page 67. The work may be pre-heated slightly to relieve the effect of expansion and contraction, but must *not be heated above a dark red*. The operator must be very careful to not bring the malleable iron at the weld to too high a heat or its malleable properties will be destroyed and the housing will be weak.

Fig. 100. Welding Broken Flange on Manifold

Manifolds. Pressed-steel manifolds should be welded according to the directions given under Light Sheet-Steel Welding, pages 46 to 50.

Cast-iron manifolds, as a rule, have only simple breaks to be repaired, such as broken flanges, Fig. 100. These should be beveled, and the parts clamped to a flat surface to keep them straight. They should then be pre-heated in the vicinity of the weld by means of the welding blowpipe before the welding is started. After the weld is completed they should be reheated evenly and then covered over and allowed to cool slowly.

Engine Cylinders. If the water jacket is cracked, the crack should be chipped out and the surface of the casting next to the groove should be cleaned by scraping. If the cylinder is cracked in

Fig. 101. Water Jacket Cut Away to Allow for Welding Cylinder Wall

the head end, it will be necessary to cut away a section of the water jacket by drilling or sawing, Fig. 101. After the cylinder head has been welded, the water-jacket section can be welded back into place, Fig. 102. Sometimes it is quite difficult to detect how far the crack really extends, therefore, care must be taken to be sure that it is chipped out its entire length.

All of the plugs and other fittings must be removed from the cylinders before pre-heating. The cylinders should be placed in

Fig. 102. Cylinder Wall Welded and Section of Water-Jacket Replaced

the pre-heating fire with the open end of the cylinder upward, Fig. 103. They may be placed on a slant if the crack is on the side of the water jacket; but they must be in such a position so there

will be no chance for dead air to remain in them. If this precaution is not taken, the cylinder walls are very likely to crack.

The welding should be carried on according to the directions given under Cast-Iron Welding, pages 59 to 67. The cylinders must be left in the charcoal fire all during the welding. It is even advisable to keep the top of the fire covered over and to weld through a hole in the asbestos paper, Fig. 103, to prevent air currents from striking the cylinder while it is hot. After the welding has been

Fig. 103. Welding Cylinders and Preparing Pre-Heating Fire for Cylinders

completed, the fire should be started up enough to heat the entire casting evenly, and should then be covered over and allowed to die out. The cylinder must not be removed until it has become cold enough to be handled with bare hands.

Protection for Machined Surfaces. The finish in the bore of the cylinder will be affected by the heating if some means is not used to protect it. The best protection that can be used is to coat it and other machined surfaces with flaked graphite and oil. This can be made into a paste and painted on, or the surfaces can be oiled

and the graphite dusted on. The latter method is really the best if carefully applied. The graphite must be coarse; the fine flake will not do.

Testing Welded Cylinders. There are several ways of testing welded cylinders. The two most generally used are by water pressure and by gasoline. In the first method, the water jacket is tightly plugged, filled with water, and then subjected to pressure by means of a hand pump. The method of using gasoline is simpler and quicker. The water jacket is plugged and filled with gasoline, Fig. 104. If there are any cracks or leaks the gasoline will work its way through and will spread out over the surface surrounding the crack or leak.

Fig. 104. Water Jacket Plugged and Welds Being Tested with Gasoline

Crankcases and Transmission Cases. It is usually necessary to remove the case from the car. But, if the arm is broken some distance from the main case, it may be welded while in position, as shown in Fig. 105. When welding in this manner, it is necessary to cover the parts near the welding with asbestos sheets to protect them from the flame of the blowpipe. The arm should be

Fig. 105. Welding Arm of Crankcase without Dismantling

will be no chance for dead air to remain in them. If this precaution is not taken, the cylinder walls are very likely to crack.

The welding should be carried on according to the directions given under Cast-Iron Welding, pages 59 to 67. The cylinders must be left in the charcoal fire all during the welding. It is even advisable to keep the top of the fire covered over and to weld through a hole in the asbestos paper, Fig. [illegible], to prevent air currents from striking the cylinder while it is hot. After the welding has been

Fig. [illegible]. Welding Cylinders and Preparing Pre-Heating Fire for Cylinders

completed the fire should be started up enough to heat the entire casting evenly, and should then be covered over and allowed to die out. The cylinder must not be removed until it has become cool enough to be handled with bare hands.

Protection for Machined Surfaces. The finish in the cylinder will be affected by the heating if [illegible] to protect it. The best protection [illegible] cover machined surfaces with [illegible] be made into a paste and pai[illegible]

pre-heated slightly by means of the welding blowpipe before the actual welding is started, and, after the welding has been completed, it should be reheated to relieve any internal strains, and must then be covered over to allow it to cool slowly.

Some operators spend a great deal of time trying to keep the bearing of the case in line, and while doing this they allow the rest of the case to twist, so that it is necessary to take a machine cut off the edges in order that they may fit the other half of the case. It is much better to keep the edges true and dress up the bearings, because it is quite likely that the bearings will have to be trued up anyway. The case should be clamped flat against two straightedges, but not too tight, or the case might crack from the strains produced when heat is applied. The case should be placed on the welding table in such a position that the welder can work on the outside and smooth off the inside without having to disturb its position.

Fig. 106. Badly Broken Transmission Case—Must Be Pre-Heated All Over

Fig. 107. Lower Half of Crankcase with Piece Broken Out—Must Be Entirely Pre-Heated

The most satisfactory method of pre-heating is to place a gas burner under the case and let it burn *without an air blast*. If an air blast is turned on, the case is liable to become overheated and

Fig. 108. Upper Half of Crankcase with Piece Broken Out and Missing

cave in. In fact, unless there are holes to allow some of the heat to escape, the case is liable to become overheated with only the soft gas flame. If the case is broken at one end, as shown in Fig. 108, it is only necessary to heat the one end; but it is very necessary to heat both sides of that end to prevent warping. If like the case shown in Figs. 106 or 107, it is best to heat the entire case. This can best be done by using two gas burners so that the heat will surely spread.

If the case is cracked or a piece is broken off, the welding should start at the inner end of the crack and move toward the edge or corner. The welding should be carried on as directed under Cast Aluminum Welding, page 71.

If a piece has been broken out and lost necessitating building

Fig. 109. Sheet-Iron Form to Back Up Section to Be Welded-In

up a section of the casting, Fig. 108, it is necessary to back-up the work by means of a piece of sheet iron bent to the required shape, Fig. 109. The welding should be started at one edge and should move across the space in a line parallel to the edge. When the added material gets almost to the opposite edge, the welding should stop, the edge of the case and the edge of the new added section should be cleaned, and then the weld completed in the same manner as for welding up a crack, Fig. 110, as outlined above.

COSTS

The cost of welding varies within wide limits for the different metals and the different classes of work. It is, therefore, not possible to give cost tables that will apply to all work. The costs given in Tables II and III are for steel work under fair conditions.

Measuring Oxygen Consumption. Oxygen is supplied compressed to 1800 pounds per square inch, in cylinders containing

TABLE II

Welding Cost Table

Thickness of Metal (in.)	Speed (ft. per hr.)	Oxygen per Linear Foot (cu. ft.)	Acetylene per Linear Foot (cu. ft.)	Cost per Linear Foot Labor.....45c Oxygen.... 2c Acetylene.. 2½c
$\frac{1}{64}$	26	0.15	0.14	$ .024
$\frac{1}{32}$	22	0.22	0.21	.030
$\frac{1}{16}$	17	0.43	0.41	.045
$\frac{3}{32}$	14	0.68	0.65	.063
$\frac{1}{8}$	11½	1.03	0.98	.083
$\frac{3}{16}$	9	1.84	1.74	.13
$\frac{1}{4}$	7	3.01	2.88	.20
$\frac{3}{8}$	4½	6.74	6.44	.40
$\frac{1}{2}$	3	13.2	12.5	.73
$\frac{3}{4}$	1½	38.7	37.0	2.00
1	1	76.7	72.9	3.81

TABLE III

Cutting Cost Table

Thickness of Metal (in.)	Speed (ft. per hr.)	Oxygen per Linear Foot (cu. ft.)	Acetylene per Linear Foot (cu. ft.)	Cost per Linear Foot Labor.....45c Oxygen.... 2c Acetylene.. 2½c
$\frac{1}{8}$	90	0.34	0.10	$ .014
$\frac{1}{4}$	74	0.55	0.17	.021
$\frac{1}{2}$	55	1.16	0.33	.040
$\frac{3}{4}$	46	1.91	0.47	.060
1	40	2.75	0.61	.082
1½	33	4.70	0.85	.13
2	29	6.97	1.06	.18
3	24	12.3	1.46	.30
4	20	19.4	1.96	.46
6	15	38.3	3.04	.87
8	11	69.7	4.60	1.55

TABLE IV

Factors for Correcting Oxygen Volumes

Deg. F.	Factor	Deg. F.	Factor	Deg. F.	Factor
100	0.929	75	0.972	50	1.020
95	0.937	70	0.981	45	1.030
90	0.946	65	0.990	40	1.040
85	0.954	60	1.000	35	1.051
80	0.963	55	1.010	30	1.061

100 and 200 cubic feet. The amount of oxygen in a cylinder can be measured quite accurately by means of the high-pressure gage on the regulator. Most of these gages are supplied with two rows

Fig. 110. Upper Half of Crankcase with Section Built-In

of figures on the dial, Fig. 111. The outer circle gives the pressure in the cylinder in pounds per square inch, and the other circle gives the per cent of oxygen remaining in the cylinder. The latter set of numbers makes the calculation very easy: e.g., if a 100-cubic foot cylinder is being used and the gage hand indicates 73, there is 73

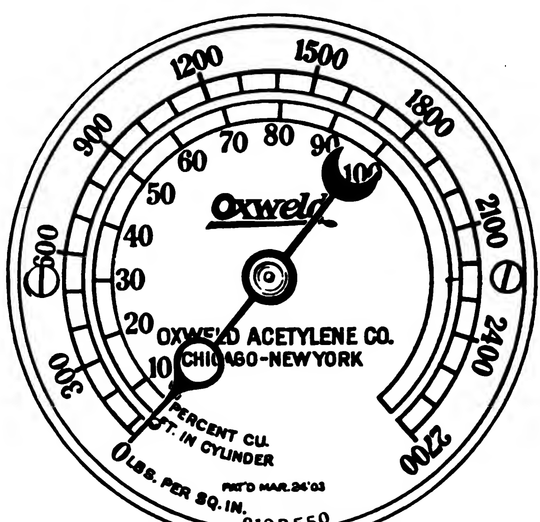

Fig. 111. Dial of High-Pressure Gage of Oxygen Regulator

cubic feet of oxygen in the cylinder. If a 200-cubic foot cylinder is being used, there is $200 \times 0.73 = 146$ cubic feet in the cylinder. The amount of oxygen indicated by the gage reading is more or less approximate and depends upon the temperature of the oxygen in the

cylinder. The correction factors given in Table IV should be used to determine the volume of the oxygen at "standard temperature", 60° F., if an accurate measurement is required, e.g., if in the case given above the temperature is 50° F., then the real volume at standard temperature would be $146 \times 1.020 = 148.9$ cubic feet.

Measuring Acetylene Consumption. The amount of acetylene in a cylinder cannot be determined by means of the high-pressure gage. All the high-pressure gage can be used for, in the case of acetylene, is to indicate very roughly the amount of acetylene in the cylinder. There is only one method that can be used to determine the amount of acetylene used, and that is to weigh the cylinder. Each pound by weight of acetylene is equal to 14.5 cubic feet. Therefore, to determine the amount of acetylene used on a certain job, it is necessary to weigh the cylinder before and after welding and calculate the volume of acetylene used from the difference in weight, e.g., if the cylinder weighs 217 pounds before welding and $207\frac{1}{2}$ pounds after welding, then $(217 - 207\frac{1}{2}) \times 14.5 = 9\frac{1}{2} \times 14.5 = 137.7$ cubic feet.

REVIEW QUESTIONS

REVIEW QUESTIONS

ON THE SUBJECT OF

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART VI

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1. Explain the action of the regulating third brush as used in the Leece-Neville system.

2. How may a Leece-Neville generator be short-circuited?

3. What must be done to increase and decrease the output of the generator in a Leece-Neville system?

4. How is regulation obtained in the North East system?

5. Explain the constant voltage method of regulation used in Remy systems.

6. What tests should be made in an Oakland when lights and ignition fail but the motor operates?

7. How may the generator in a 1917 Maxwell be tested?

8. How is regulation obtained in the Splitdorf system?

9. Explain the action of the touring switch in the U.S.L. system.

10. What starting system is used on the 1917 Mercer?

11. What special features does the U.S.L. "Nelmi" system include?

12. How may a ground in the starting system be located in a Scripps-Booth "Four"?

13. How may an ammeter test for short-circuits be made?

14. What should be done when a generator of the voltage-regulator type fails to charge the battery properly?

15. Sketch the Hupmobile installation.

16. Explain the action of the Wagner switch.

REVIEW QUESTIONS

ON THE SUBJECT OF

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART VII

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1. Give the method of mounting a generator.

2. What adjustments must be made before installing a generator?

3. In a generator installation can the lights be used if the battery has been removed?

4. How would you determine that the regulator was not working properly in a Gray & Davis installator?

5. What lamps are required in a Gray & Davis Ford installator?

6. Why is no provision made for oiling the Gray & Davis generator bearings?

7. Describe the method of testing a generator with an ammeter.

8. Sketch the Heinze-Springfield Ford installation.

9. Sketch the Fisher Ford installation.

10. What must be done if it is necessary to run the generator with the battery disconnected, in the North East system?

11. Sketch the North East dash wiring.

12. How can a horizontal chain be adjusted?

13. At about what car speed should the battery cut-out close, in the Heinze-Springfield system?

REVIEW QUESTIONS

ON THE SUBJECT OF

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART VIII

1. What causes sulphating and what can be done with a badly sulphated plate?

2. If a battery has been kept in an undercharged condition for some time, what percentage of the time necessary to charge it originally will now be required to charge it?

3. What is gassing and what does it indicate?

4. Give the correct method for adjusting the specific gravity of the electrolyte in a cell.

5. What may be learned from a hydrometer test and how should the tests be carried out?

6. If, in making a test, a voltage reading of 1.9 volts per cell and a hydrometer reading of 1.220 or more are obtained, what does this indicate?

7. Outline the proper method of cleaning a battery and replacing a broken jar.

8. Show by a sketch the proper method for discharging battery through a water resistance.

9. Give two methods of lead burning.

10. What is the difference between dry and wet storage? Outline the proper procedure in each case.

11. When should a battery be given an equalizing charge?

12. Discuss the proper methods of battery charging, including descriptions of motor-generators and rectifiers.

13. How should a battery be taken care of in the winter?

REVIEW QUESTIONS

ON THE SUBJECT OF

MOTORCYCLES

1. How many cylinders has the conventional American motorcycle, and what type motor is usually used?

2. In what way has the installation of high-speed motors influenced the design of motorcycles?

3. Give a complete description of the Smith motor wheel.

4. What is a cyclemotor?

5. Give specifications for the engine used in the Excelsior No. 9.

6. What American companies manufacture 4-cylinder motorcycles?

7. Give complete specifications for the engine used in the Henderson motorcycle.

8. What is the difference between a 4-cycle and a 2-cycle engine?

9. Describe the spring frame construction used in the Merkel.

10. What two main types of frames are used in motorcycle construction?

11. How are the crankshafts fitted on flywheels in 5-cylinder engines?

12. Describe the action of the Indian roller-cam oil pump.

13. What type of transmission is used in the Harley-Davidson?

14. Describe the principle of operation of the Midco magneto-generator as used on the Excelsior.

15. Describe the Harley-Davidson commercial van.

REVIEW QUESTIONS

ON THE SUBJECT OF

WELDING IN AUTOMOBILE REPAIR SHOPS

1. Name two methods of welding heavy sheet steel and describe one of them.

2. Give the characteristics of the low-pressure acetylene generator.

3. Name and describe the characteristics of the three types of blowpipe flames.

4. What kind of welding rod and what flux are used in welding copper?

5. In what essentials does the cutting blowpipe differ from the welding blowpipe?

6. Give the method of measuring the oxygen used in a welding job.

7. Describe the essentials of an electric welding outfit.

8. Draw a simple diagram showing the essential parts of an acetylene welding outfit and their location.

9. Describe the process of welding up a hole which has been accidentally made in the work.

10. Why is pre-heating important?

11. Give the important distinctions between the treatment of steel, cast iron, aluminum, and copper during the welding process.

12. What is the action of the acetylene regulator?

13. Give the various steps in butt-welding a pair of steel plates, showing how to manipulate the blowpipe.

14. What are the principal factors in the production of defective welds and what can be done to avoid them?

INDEX.

INDEX

The page numbers of this volume will be found at the bottom of the pages; the numbers at the top refer only to the section.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

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Note.—For page numbers see foot of pages.

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